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AN
INTRODUCTION
TO
HUMAN ANATOMY

BY
WILLIAM TURNER, M.B.
PROFESSOR OF ANATOMY IN THE UNIVERSITY OF EDINBURGH
MEMBER OF THE GENERAL MEDICAL COUNCIL.

PART II.

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AN
INTRODUCTION
TO
HUMAN ANATOMY
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BY
WILLIAM TURNER, M.B.
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PREFACE.

PART I. of this Introduction to Anatomy was published in February 1875. By the publication of Part II. the work is completed. With a few exceptions, the illustrations in this Part have been drawn on the wood, from original material and specimens, by my assistant, Dr J. Halliday Scott, to whom I desire to express my thanks for the care he has taken in delineating the several objects. Except when stated otherwise, the microscopic objects, from which the illustrations of the minute anatomy of the organs have been taken, were prepared with his customary care and skill by my assistant, Mr A. B. Stirling. My thanks are also due to my friend, Dr J. A. Russell, for the trouble he has bestowed in revising the proof-sheets.

MARCH 1877.

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CHAPTER VII.

VASCULAR SYSTEM.

THE human body and the bodies of all the more highly organized animals are traversed by a system of closed, branching tubes or pipes, technically called Vessels, some of which in man are nearly an inch in diameter, others so small as to require a microscope for their examination, others again of every intermediate size. In connection with the vessels is a central organ, the Heart. The heart and the vessels collectively constitute the Vascular System. When examined after death the vessels are frequently found to be empty, but during life they contain fluids. Some contain Blood, and form the Sanguiferous or Blood-vascular system; others contain Lymph, and form the Lymph-vascular system. The lymph-vascular system is not distinct from and independent of the blood-vascular system, but communicates with it at several points. The vascular system is a hydraulic apparatus, possessing a pump, pipes, and valves. The heart is the pump, which works, not by the movements of a piston, but by the contraction of its muscular walls; the vessels are the pipes which convey the contained fluid, and they are provided in certain localities with valves for directing its flow.

BLOOD-VASCULAR SYSTEM.

The blood flows through the blood-vascular system in a given direction, and its movement is called the *circulation of the blood*. In man and the higher vertebrates the heart is a double organ, *i.e.*, it consists of a right and a left portion, intimately united to, but not directly communicating with, each other. The blood which flows from its right side passes through vessels which traverse the lungs, and is conveyed to the left side of the heart: this is called the *pulmonary circulation*. The blood which flows from the left side passes through vessels which traverse the body generally, and is conveyed to the right side of the heart: this is called the *systemic circulation*. The complete circulation, *i.e.*, the passage of a drop of blood, from one side of the heart, back again to the same side, can only be effected by passing through both the pulmonic and systemic circulations. Hence the complete circulation is sometimes called a *double circulation*.

The vessels which carry the blood away from the heart are called *arteries*. The arteries branch and terminate in a network of vessels of microscopic size called *capillaries*. The vessels which convey the blood back to the heart are *veins*, and the veins arise from the capillaries. The arteries and veins do not communicate directly with each other, but centrally through the intermediation of the heart, and peripherally through the intermediation of the capillaries. Hence, both in the pulmonary and systemic circulations, the blood in its passage from the arteries into the veins must go through capillaries. The blood which flows from the left side of the heart into the systemic arteries is

bright red, pure or arterial blood; as it traverses the systemic capillaries it parts with certain of its constituents to nourish the organs and tissues, and as it also receives from them waste products it becomes impure blood; in which condition it flows back to the right side of the heart by the systemic veins as dark red, or venous blood; hence the right side of the heart is often called the venous side. The blood which flows from the right side of the heart along the pulmonary artery is this dark-red, venous blood; as it traverses the pulmonary capillaries it is purified by the action of the air in the lungs, it parts with carbonic acid, takes up oxygen, and is changed into arterial or pure blood, in which condition it flows back by the pulmonary veins to the left side of the heart, which consequently is called the arterial side. The object of the pulmonary circulation, therefore, is to reconvert into pure blood the blood which has been rendered impure during its passage through the systemic capillaries.

The anatomy of the heart, and of the pericardium, the bag in which it is enclosed, will first be described.

THE PERICARDIUM.

The Pericardium is a bag which envelopes the heart. It is situated in the cavity of the thorax, and occupies the middle division of the space called *mediastinum*, between the two lungs; it lies therefore behind the sternum, and in front of the spinal column, but projects more to the left than to the right side of the mesial plane. Laterally the pericardium is in relation to the lung, pleura, and phrenic nerve; but the lungs, when inflated during inspiration,

overlap the pericardium, and lie between it and the sternum and costal cartilages. The pericardium is separated from the spine by the contents of the posterior mediastinum. It is attached below to the central tendon of the diaphragm, and blends above with the sheaths of the great vessels which pass to and from the heart. Two fibrous bands, the *sterno-pericardiac ligaments* of Luschka, are connected to its anterior surface; the *superior ligament* springs partly from the back of the manubrium, and is partly continuous with the cervical fascia; whilst the *inferior ligament* proceeds from the inner side of the base of the xiphisternum.

Structure.—The pericardium is formed externally of a

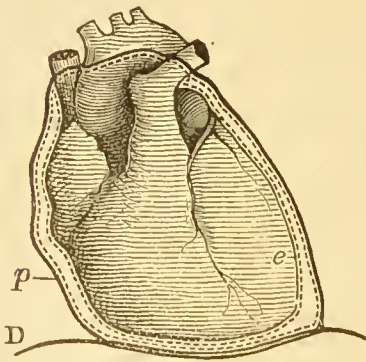


FIG. 115.—The Heart within the Pericardium. The dotted line represents the arrangement of the serous layer; *e*, the epicardium; *p*, the pericardium; *D*, the diaphragm.

strong fibrous membrane, which is attached by areolar tissue to the diaphragm, the wall of the œsophagus and the attached surface of the two pleuræ.

When the pericardium is cut open its inner surface is seen to possess a smooth, free, glistening, serous aspect, similar to the inner surface of the

dura mater. This is due to the interior of the bag being lined by a single layer of squamous endothelium. Where the fibrous membrane of the pericardium is prolonged on to the aorta, the pulmonary artery and veins, and the venæ caviæ, the serous endothelial lining of the bag

is reflected as a covering upon those great vessels, and is continued from them over the exterior of the heart itself, so as to give it a covering, possessing a smooth, free, ^{ir}glistening serous surface, which is called the visceral layer of the pericardium, or the *epicardium*. The serous lining does not form a separate covering for the aorta and the pulmonary arterial trunk, but encloses them in a common sheath; each of the great veins has its own investment, though the covering given to the inferior cava is very short, as that vein opens into the right auricle immediately on piercing the fibrous membrane of the pericardium. A fold of the pericardium, named by Marshall the *vestigial fold*, is situated between the left pulmonary artery and immediately subjacent pulmonary vein. This fold marks the position of a vessel present in the embryo heart, and known as the left superior vena cava, or duct of Cuvier. The free surface of the epicardium glides upon the serous lining of the bag during the movements of the heart, and the two surfaces are lubricated by a little serous fluid; which under certain pathological conditions may increase in quantity, and produce dropsy of the pericardium.

THE HEART.

The Heart is a hollow muscle enclosed in the pericardium, and lying in the thoracic cavity in the middle division of the mediastinal space between the two pleural membranes. It is the great motor organ for the circulation of the blood, and, though varying in its dimensions with the amount of blood that it contains, may be said to be of much the same size as the fist of the individual. It

measures about five inches in length, by three and a half in its greatest breadth, and is about two and a half inches in thickness. Its weight is from nine to ten ounces.

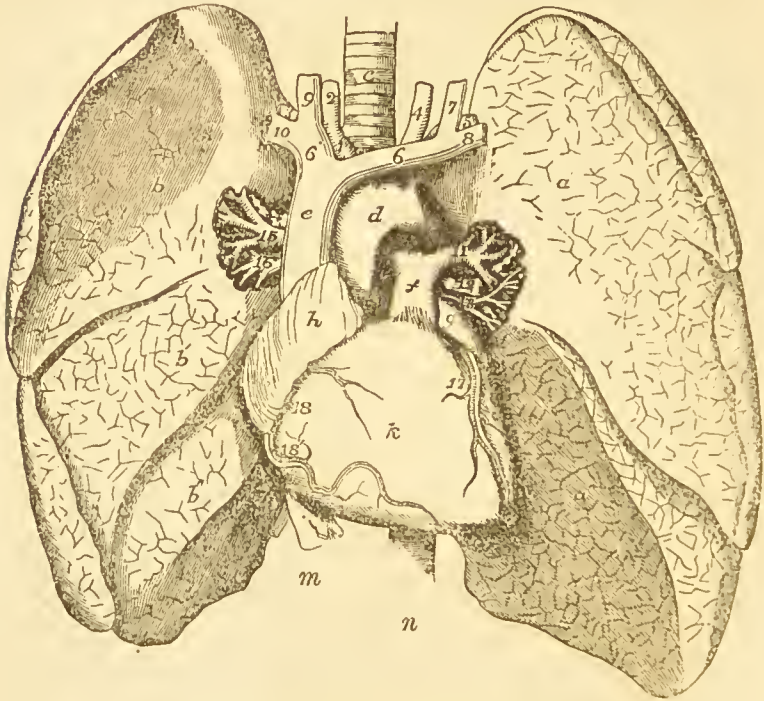


FIG. 116.—The Thoracic Viscera.

In this diagram the lungs are turned to the side, and the pericardium removed to display the heart. *a*, upper, *a'*, lower lobe of left lung; *b*, upper, *b'*, middle, *b''*, lower lobe of right lung; *c*, trachea; *d*, arch of aorta; *e*, superior vena cava; *f*, pulmonary artery; *g*, left, and *h*, right auricle; *i*, right, and *j*, left ventricle; *m*, inferior vena cava; *n*, descending aorta; *1*, innominate artery; *2*, right, and *4*, left common carotid artery; *3*, right, and *5*, left subclavian artery; *6*, *6*, right and left innominate vein; *7* and *9*, left and right internal jugular veins; *8* and *10*, left and right subclavian veins; *11*, *12*, *13*, left pulmonary artery, bronchus, and vein; *14*, *15*, *16*, right bronchus, pulmonary artery, and vein; *17* and *18*, left and right coronary arteries.

The heart is frequently compared in shape to a blunt cone, and is directed obliquely from above downwards, from right to left, and from behind forwards. For descriptive purposes it may be regarded as possessing a base, an

apex, an anterior and a posterior surface, a right and left border. The base lies backwards, upwards, and to the right, opposite the 4th to the 8th dorsal vertebræ. The apex is directed downwards, forwards, and to the left, opposite to the interval between the 5th and 6th left ribs, where it comes into relation with the anterior wall of the chest about $1\frac{1}{2}$ inch below the nipple, and $3\frac{1}{2}$ inches from the middle line of the sternum. The anterior surface is convex, and in relation to the back of the lower half of the sternum, of the 3d, 4th, 5th, and 6th left costal cartilages, and the 3d, 4th, and 5th right costal cartilages. The pleuræ and lungs overlap this surface of the heart, being separated from it by the pericardium. The posterior surface is flattened, and in relation to the diaphragm. The right border is thin when compared with the left border, which is shorter and more rounded. About two-thirds of the heart are situated to the left of the mesial plane of the thoracic cavity.

The outer surface of the heart is marked by grooves, which indicate externally its division internally into four chambers or cavities. One of these grooves, called the *auriculo-ventricular groove*, runs around the heart, both on the anterior and posterior surfaces, from border to border, and marks off the two auricles from the two ventricles. This groove is more distinct on the back than on the front of the heart, for it is concealed anteriorly by the origins of the aorta and the pulmonary artery. Two longitudinal grooves extend from the base to the apex of the heart, one on the anterior surface, the other on the posterior. They indicate the separation of the heart into a right and left portion or side. The right side consists of the right auricle and right ventricle, the left side of the left auricle

and left ventricle. The two longitudinal grooves are most distinctly marked on the ventricular portion of the heart, where they are called the *ventricular grooves*. The *anterior ventricular groove* is nearer to the left than to the right border, whilst the *posterior ventricular groove* is nearer to the right border. The two grooves become continuous with each other immediately to the right of the apex of the heart. In one mammal, viz., the dugong, the ventricular grooves are deepened at the apex into a wide cleft, extending between the two ventricles.

To study the chambers of the heart incisions should be made through the walls of the auricles and ventricles, when all these chambers will be seen to be lined by a smooth membrane, the *endocardium*, which is continuous on the one hand with the lining membrane of the several veins, and on the other with the lining membrane of the arteries, which communicate with the chambers.

The *Right Auricle* occupies the right part of the base of the heart. It consists of a large dilated portion, the *sinus venosus*, and of a small ear-shaped appendage, the *auricula*. Its muscular wall is smooth internally, except in the auricula and adjacent anterior wall of the sinus venosus, where it is thrown into parallel ridges, like the teeth of a comb, named *musculi pectinati*. Into the sinus venosus open the great systemic veins or *venæ cavæ*. The *superior vena cava* conveys to the auricle the systemic blood that has been circulating in the body above the diaphragm; it opens by a patent mouth into the upper and back part of the sinus venosus. The *inferior vena cava* conveys to the auricle the blood that has been circulating in the parts of the body below the diaphragm; it opens into the lower and

back part of the auricle, and at its mouth is the *Eustachian valve*. The valve of Eustachius is a crescent-shaped fold of the endocardium, situated in front of the mouth of the inferior cava: its anterior cornu is continuous with the annulus ovalis on the auricular septum, its posterior cornu is lost on the outer wall of the auricle. The valve in the adult is often perforated with holes, or is so rudimentary as to be functionless, but in the fœtus it is a large and important structure. Close to the orifice of the inferior cava is the mouth of another large vein, the *coronary venous sinus*, which returns most of the blood from the walls of the heart itself; this orifice also possesses a small crescent-shaped valve, the *coronary* or *Thebesian valve*. Several minute openings, the *foramina Thebesii*, scattered over the inner wall of the auricle, are the mouths of small veins ramifying in the wall itself. Through these various orifices the venous blood pours into the auricle, and then flows into the right ventricle through a large orifice, the *right auriculo-ventricular opening*, which lies at the lower part of the auricle in front of the inferior cava. The right auricle is separated by a partition, the *auricular septum*, from the left auricle. On the surface of this septum is a depression, the *fossa ovalis*, surrounded by a raised border, the *annulus ovalis*, with which border the inner end of the Eustachian valve is continuous. Before the birth of the child the septum is perforated by a hole, called *foramen ovale*, through which the blood directed by the Eustachian valve flows from the inferior vena cava into the left auricle. This foramen closes up after the birth of the child, but sometimes a small orifice, directed obliquely through the septum, persists even in the adult.

The *Right* or *Anterior Ventricle* forms the right border, a large part of the anterior surface, but only a small part of the posterior surface of the heart. It is shaped somewhat like a flattened cone, its apex being directed downwards towards the apex of the heart, its base to the

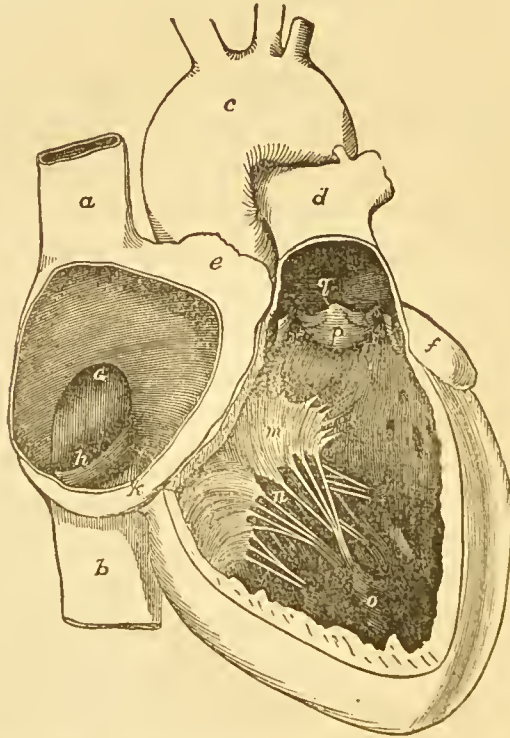


FIG. 117.—Cavities of the right side of the Heart.

a, superior, and *b*, inferior vena cava; *c*, arch of aorta; *d*, pulmonary artery; *e*, right, and *f*, left auricular appendage; *g*, fossa ovalis; *h*, Eustachian valve; *k*, mouth of coronary vein; *l*, *m*, *n*, cusps of the tricuspid valve; *o*, *o*, papillary muscles; *p*, semilunar valve; *q*, corpus Arantii; *r*, lunula.

corresponding auricle. The inner surface of its muscular wall is very irregular, owing to the muscular bundles being elevated into strong reticulated ridges, called *columnæ carneæ*. Two, or it may be three, of these fleshy columns

project like nipples or big papillæ into the cavity of the ventricle, and are called *musculi papillares*. Attached to the free apex of each papillary muscle are several fibrous threads, the *chordæ tendineæ*, which, by their opposite extremities, are connected to the segments of a large valve situated around the opening between the right auricle and ventricle. The right auriculo-ventricular opening, situated at the base of the ventricle, is sufficiently large to admit three fingers, and possesses a valve, which consists of three large pointed segments or cusps (hence the name *tricuspid* given to it), between which three small intermediate cusps lie. One of the large cusps is opposite the anterior wall of the ventricle, another opposite the posterior, whilst the third is to the left between the auriculo-ventricular opening and the conus arteriosus. The cusps are flattened triangular folds of the endocardial membrane connected by their bases around the opening; when the valve is not in action the apex of each cusp hangs pendulous in the ventricle: one surface is smooth, and looks to the cavity of the ventricle, the other surface is rough, and is directed to its wall; to this rough surface, to the apex, and to the edges of the cusp, the *chordæ tendineæ* are attached. As the *musculi papillares*, from which the *chordæ tendineæ* spring, are opposite the intervals between the cusps, the *chordæ tendineæ* from any given papillary muscle divide themselves into two groups, one for each of the two cusps between which it is situated. In the mammalian heart, and as Rolleston has shown in the heart of the bird, a band not unfrequently passes from the base of the anterior papillary muscle to the septal wall of the ventricle. As it prevents over-distension of the

ventricle, it has been named the *moderator band*. In the bird the right auriculo-ventricular valve is a muscular structure.

The base of the right ventricle forms to the left and in front of the auriculo-ventricular opening, a funnel-shaped prolongation, the *conus arteriosus*, from which the *pulmonary artery* arises, through the intervention of a strong fibrous ring. Surrounding the mouth of this artery is a valve called *semilunar*, which consists of three semilunar segments. Each segment is attached by its convex border to the artery where it springs from the ventricle. The opposite border is free, and possesses at its centre a minute nodule, the *corpus Arantii*, from which slender fibrous threads curve outwards at the free border and in the substance of the valve to strengthen it. A thin lunated portion lies immediately within the free border. One surface of the valve is convex, and directed to the lumen (*i.e.*, the space contained by the walls) of the artery; the other is concave, and directed to the wall of the artery, and between it and the wall is a pouch named *sinus of Valsalva*. The pulmonary artery extends upwards and to the left for about $1\frac{3}{4}$ inch, and then divides into two branches, one for each lung. The right ventricle is completely separated from the left by the *ventricular septum*, which passes obliquely from left to right, and from before backwards, so that it forms the posterior wall of the right ventricle and the anterior wall of the left. The apex of the septum is at the apex of the heart, its base or highest part is between the two auriculo-ventricular openings. Thurnam pointed out that the highest part is not formed of muscular fibres, but of the endocardial membrane, strengthened by fibrous

tissue. This part is called *pars membranacea septi*. In very rare cases it is defective, and then an opening of communication exists between the two ventricles.

The *Left Auricle* is situated at the posterior and left part of the base of the heart, and, like the right auricle, consists of a dilated *sinus venosus* and an ear-shaped appendage, the *auricula*. Its muscular wall has a smooth surface internally, except in the *auricula*, where the comb-like *musculi pectinati* occur. Opening into the posterior part of the *sinus venosus* are the orifices of the four *pulmonary veins*, two from the right, two from the left lung; these orifices are without valves. At the lower part of the auricle is the large *left auriculo-ventricular orifice* of communication between it and the base of the left ventricle. The auricular septum is marked by a slight depression, which indicates the position of the *foramen ovale* in the foetal heart. The auricular appendix is somewhat longer than on the right side, and curves forward by the side of the pulmonary artery.

The *Left or Posterior Ventricle* forms the left border, the apex, a large part of the posterior surface, but only a small part of the anterior surface of the heart. It is conical in form, its apex is at the apex of the heart, the base at the corresponding auricle. As in the right ventricle, the inner surface of its wall is elevated into fleshy columns, two of which project like nipples into the cavity and form large *musculi papillares*, which have *chordae tendineae* connected with them. The left auriculo-ventricular opening, situated at the base of the ventricle, is large enough to admit two fingers. It possesses a valve, which consists of two large pointed segments or cusps, hence it is called the

bicuspid valve; and as these cusps are placed one in front of the other like the segments of a bishop's mitre, the name *mitral valve* is often given to it. The cusps agree in shape, general arrangement, and mode of attachment with those of the tricuspid valve, but they are stronger. The more posterior segment lies in relation to the posterior wall of the ventricle: the more anterior segment lies obliquely between the auricular and aortic orifices, and is characterized by being smooth on both its surfaces. At the angles between the bases of attachment of the two large cusps of this valve two small intermediate cusps are situated. The *chordæ tendineæ*, springing from each musculus papillaris separate, as on the right side, into two groups, one for each of the two cusps.

From the base of this ventricle the great systemic artery or *aorta* arises through the intervention of a strong fibrous ring. The mouth of the aorta is surrounded by a three-segmented *semilunar valve*, similar in form, mode of attachment, and structure to the semilunar pulmonary valve, but with thicker and stronger segments, and possessing more strongly marked *sinuses of Valsalva*. The segments are placed, one in relation to the posterior wall of the aorta, and two to its antero-lateral wall. The base of each ventricle has therefore two openings in it, one for communication with the auricle, the other with the great artery arising from the ventricle. The auriculo-ventricular openings are the most posterior, and almost in the same transverse plane; the aortic opening lies in front of the interval between the two auriculo-ventricular, and the pulmonary opening is in front of the aortic.

The relation which these openings have to the anterior

wall of the chest is of importance in connection with the diagnosis of disease of the valves. The pulmonary opening lies behind the articulation of the third left costal cartilage with the sternum, and the trunk of the pulmonary artery ascends, prior to its bifurcation, as high as the level of the second left costal cartilage. The aortic opening, somewhat lower down than the pulmonary, and posterior to it, is situated behind the left border of the sternum, on a level with the third intercostal space. The right auriculo-ventricular or tricuspid opening, lies behind the sternum, on a level with the fourth pair of costal cartilages. The left auriculo-ventricular or mitral opening is on the same plane as the right tricuspid opening, but to its left side.

Structure.—The walls of the cavities of the heart are chiefly formed of striped muscular fibre, over the contractions of which the Will exercises no control; but, in addition, connective tissue, a little fibro-cartilaginous tissue, the endocardium, and vessels and nerves are also found.

The muscular fibres are collected into fasciculi, which have a reticulated arrangement, and the fibres themselves branch and again unite to form a complicated network. The fibres of the walls of the auricles are distinct from those of the ventricles, so that the auricular and ventricular compartments are connected together, not by an interchange of muscular tissue, but by an intermediate ring-like arrangement of fibres of connective tissue, known as the *auriculo-ventricular rings*. The muscular fasciculi of the auricles are arranged in two strata. The deeper stratum consists of fibres proper to each auricle, some of which run obliquely in the wall, others surround the auricula, and others are prolonged in rings into the coats of the venæ

cavæ and pulmonary veins, whilst fibres extend longitudinally and obliquely along the wall of the coronary venous sinus. The superficial stratum consists of fasciculi, which run obliquely from one auricle to the other on both the anterior and posterior surfaces, and are said to be prolonged into the auricular septum.

The muscular wall of the ventricles is much thicker than that of the auricles, and the wall of the left ventricle is about three times thicker than the right. The fibres vary in their direction in different parts of the thickness of the ventricular walls. The superficial external fibres run on the anterior surface of the ventricles obliquely from above downwards, and from right to left, and dip into the anterior ventricular groove to enter the septum, whilst on the posterior surface they extend across the posterior ventricular groove. At the apex of the heart they turn inwards in a whorl-like manner, and, as was known to Lower and Gerdy, become continuous with superficial fibres on the inner wall of the ventricle. At the base of the ventricles, some of the superficial external fibres are attached to the auriculo-ventricular and arterial rings, but the greater number turn round the border of the auriculo-ventricular openings, and, as Pettigrew has shown, become continuous with the superficial internal fibres, which run obliquely in the reverse direction. The internal fibres are also prolonged into the muscoli papillares, the chordæ tendineæ springing from which serve therefore as tendons of insertion of these muscles. Deeper in the substance of the wall the fibres are arranged in different degrees of obliquity, and about the centre of the thickness of the wall are seen to lie in the horizontal plane. Various anatomists have

described these fibres of the ventricles as arranged in layers. Lower recognised two layers spirally crossing each other; Haller, three; Wolff, three in the right and six in the left ventricle. Pettigrew at one time believed he could dissect nine layers, but has subsequently reduced the number to seven—three external, a fourth or central, and three internal. He conceives that the fibres of the three external layers run in a spiral direction from left to right downwards, the first layers being more vertical than the second, and the second than the third, whilst the fibres of the fourth or central layer are horizontal. The three internal layers also run spirally, but in the reverse direction from the external, with which they become continuous both at the base and apex. The subdivision of the ventricular wall into such precise and determinate layers as is implied in the descriptions of Pettigrew is, however, an artificial procedure. There can be no doubt, as his dissections so beautifully show, that the direction of the fibres in the ventricular wall varies at different depths; but owing to the reticulated arrangement of the fibres, not only are those connected together which lie in the same plane in one of the so-called layers, but they also anastomose with the fibres in the layers immediately superjacent and subjacent to it. Hence when one layer is peeled off, that immediately subjacent exhibits, not a smooth face, which it would have done had the definition of the layers been distinct, but a rough appearance, due to the rupture of intermediate connecting muscular fibres. The fasciculi form, therefore, a network, the strands of which are arranged in two directions, one parallel to the surfaces of the ventricles, the other passing from the inner to the outer surface of

the wall. Owing to these connections the substance of the wall of the ventricle, as Henle's dissections show, may, with the exception of the superficial internal and superficial external fibres, be split up into lamellæ, which extend either horizontally, obliquely, or in an arched manner through the wall between its two surfaces; and the surfaces of those lamellæ are not parallel to the wall of the ventricle, but are directed upwards and downwards.

The connective tissue of the heart is only small in quantity between the muscular fasciuli. At the base of the ventricles it is collected in a ring-like arrangement around the auriculo-ventricular and arterio-ventricular openings, and forms the auriculo-ventricular and arterial fibrous rings. These rings are in part composed of a tissue resembling white fibro-cartilage and in part of elastic fibres. In some animals, as the ruminants, a bone, the *os cordis*, is developed in the interval between the aortic and auriculo-ventricular openings. The rings give origin to some of the muscular fibres of the ventricles and auricles, and send bundles of fibrous tissue into the auriculo-ventricular and aortic valves, whilst the arterial rings are prolonged into the middle coats of the aorta and pulmonary artery. Owing to the close relation between the base of the anterior cusp of the mitral orifice and the aortic orifice, the fibrous rings of these two openings become blended together.

The endocardium consists of connective tissue and elastic fibres, with a layer of endothelium on the free surface; and Schweigger-Seidel has also described smooth muscular fibres in it. Hence, as Lusehka has stated, the endocardium represents not merely the inner coat of the blood-vessels but all the structures of the vascular wall. Purkinje de-

scribed fibres beneath the endocardium, which are now regarded as imperfectly formed striated muscular fibres. The valves are folds of the endocardium, enclosing fibres continuous with those in the fibrous rings; the cuspidate auriculo-ventricular valves receive fibres from the chordæ tendineæ, and muscular fibres, continuous with those of the auricles, are prolonged for a short distance into the cusps. The semilunar and cuspidate valves are vascular; fine arteries, derived from the coronary, pass between the two layers of each valve, and terminate in a capillary plexus.

The heart is well supplied with blood, not by the blood which flows through its cavities, but by two special coronary arteries which ramify in its walls, and end in numerous capillaries lying between the fibres. From these capillaries the coronary veins arise, which join to form the coronary venous sinus. Lymphatic vessels occur both in the endocardium and pericardium, and apparently ramify in the muscular wall. The nerves of the heart have been dissected especially by Scarpa, Remak, Lee, and Pettigrew, and numerous small ganglia described in connection with them (p. 317).

The blood flows from the capillary networks along the great veins into the auricles; the systemic veins convey it into the right auricle, the pulmonary veins into the left. The blood is then propelled by the contraction of the muscular walls of the auricles through the auriculo-ventricular openings, the valves of which open outwards, into the ventricles. When the ventricles are distended, their muscular walls contract and force the blood into the arteries—the right ventricle into the pulmonary artery, the left into the aorta—the valves at the mouth of each artery opening

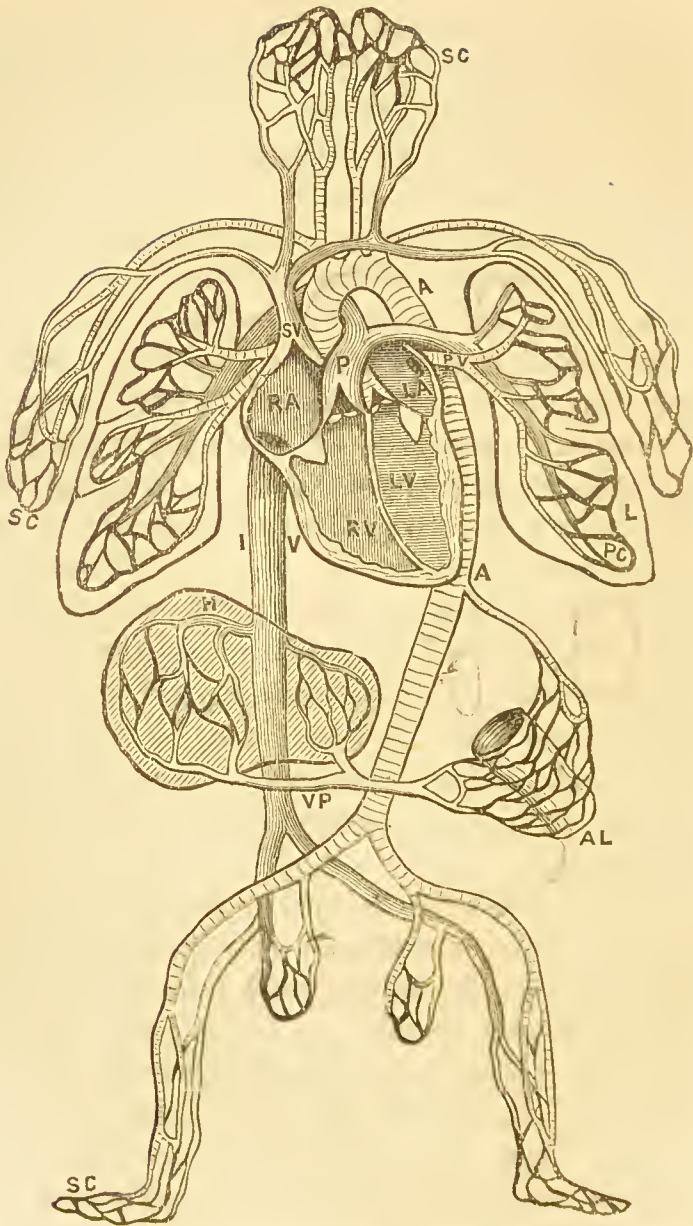


FIG. 118.—Diagram of Blood-vascular system. AA, aorta; P, Pulmonary arterial trunk; PV, left pulmonary vein; SV, superior vena; IV, inferior vena; PC, pulmonary capillaries; SC, systemic capillaries; RA and RV, right auricle and ventricle or pulmonic heart; LA and LV, left auricle and ventricle or systemic heart; H, hepatic vein in the liver; AL, alimentary canal; VP, portal vein; L, lung.

outwards to allow of the free passage of the fluid. To prevent, during the ventricular contraction, the regurgitation of blood into the auricles, the auriculo-ventricular valves are floated away from the sides of the ventricle across their respective openings, and by the apposition and slight overlapping of their edges temporarily close the opening. The tilting upwards of the valves into the auricle is prevented by the contraction of the muscoli papillares and their connection with the cusps of the valve through the chordæ tendineæ. Pettigrew has shown that casts of the ventricular cavities, more especially of the left, have the form of a double cone, spirally twisted from right to left, and has described the blood as forced in spiral streams against the under surface of the segments of the valve, which are twisted and wedged into each other so as to prevent regurgitation. The propulsion of the blood into the arteries distends the elastic wall of those tubes; but when the ventricular contraction has ceased, the elastic wall recoils, and the blood is propelled onwards into the capillaries in the course of the circulation. The regurgitation of the blood from the arteries into the ventricles is prevented by the closure of the semilunar valves, the segments of which are thrown across the arterial orifices through the pressure exercised by the elastic rebound of the arterial walls on the column of the blood in the lumen of the artery and in the sinuses of Valsalva.

If we commence, therefore, at the pulmonary capillary system, where the blood becomes pure or arterial, we find that it flows, as arterial blood, successively into the pulmonary veins, left auricle, left ventricle, aortic system of arteries, and systemic capillaries. In the systemic capil-

laries it becomes venous blood, and in that condition flows into the systemic veins, right auricle, right ventricle, pulmonary system of arteries, and pulmonary capillaries.

THE ARTERIES.

These vessels were named arteries by the older anatomists, on the supposition, now known to be erroneous, that they contained air. The term artery is now employed to express a blood-vessel, which, arising either directly or indirectly from the heart, conveys blood away from that organ into a network of capillaries. Arteries divide and subdivide into smaller vessels in their course, and to the individual branches descriptive names are applied. Some of these names express the position of an artery, as subclavian, axillary; others, the organ in which it is distributed, as pulmonary, hepatic; others a peculiarity in its course, as circumflex, coronary. The branches of arteries may be either *collateral* or *terminal*. The collateral branches arise from the sides of the parent artery either at an acute, a right, or an obtuse angle. Terminal branches arise at an acute angle by the bifurcation of the parent artery, which is the most common form, or by the breaking up of the artery into a cluster of branches. An artery does not diminish in calibre from the origin of one branch to the origin of the next succeeding branch. The calibre of each branch is less than that of the stem from which it arises, but the sum of the calibre of the different branches is greater than that of the stem from which they spring.

Branches which arise either from the same artery or

from different arteries may be distributed in a common locality, may there unite together, and form what is called an *inosculation* or *anastomosis*, so that the blood from one artery may thus flow from it into another. The inosculations of the branches of the same or of adjacent arteries are of great importance with reference to the mode in which a part receives its supply of blood when the main artery is obstructed, for through these anastomoses secondary channels are provided along which the blood may flow to a part. The most common anastomosis is by the formation of loops between adjacent branches; but sometimes, as when the two vertebral arteries join to form the basilar, a convergence of two almost straight arteries takes place; and in other cases, as where the two anterior cerebral arteries are joined together by the anterior communicating, a connecting branch passes transversely across the mesial plane. A more complex form of anastomosis is when an artery (and a similar arrangement is sometimes found in veins) rapidly subdivides into numerous branches, which may again join to form a trunk either with or without the formation of a plexus. This is called a *rete mirabile*, an arrangement not uncommon in the cetacea, and also found in the internal carotid arteries of ruminants, in the mesenteric arteries of the pig, in the arteries of the limbs of the sloths and lemurs, in the caudal arteries of the armadillo, and in the arterial system of fishes. The only examples of a rete in the human body are the glomeruli, or convoluted Malpighian tufts of the kidney, and the arterial distribution in the coccygeal and intercarotic bodies.

PULMONARY GROUP OF ARTERIES.

The pulmonary group of arteries consists of the trunk of the pulmonary artery and of its branches. (Fig. 116, f. 11, 15.)

The TRUNK of the PULMONARY ARTERY arises from the conus arteriosus of the right ventricle. It is about two inches long, and passes upwards, backwards, and to the left as high as the level of the second left costal cartilage, when it divides into the right and left pulmonary branches. In its course it lies at first in front of the origin of the aorta, and then passes to the left of the ascending part of the aortic arch, to bifurcate into its two terminal branches immediately below the transverse part of the arch. It is attached to the aorta by areolar tissue, and the two are invested by a common envelope of the serous layer of the pericardium.

The RIGHT PULMONARY ARTERY passes to the right almost transversely behind the ascending aorta and the superior vena cava to the root of the right lung, where it lies between the right pulmonary vein and the bronchial tube.

The LEFT PULMONARY ARTERY is shorter than the right. It runs in front of the descending aorta to the root of the left lung, where it lies above the bronchus and pulmonary vein. A fibrous cord, the remains of the ductus arteriosus, is attached on the one hand to the left pulmonary artery close to its origin, and on the other to the lower surface of the transverse part of the aortic arch. In the foetus the ductus arteriosus is a short wide vessel, which conveys blood directly from the pulmonary artery into the aorta. After the birth of the child it is no longer required,

and shrivels up into a fibrous cord. The distribution of the pulmonary arteries in the lungs will be afterwards described.

AORTIC OR SYSTEMIC GROUP OF ARTERIES.

This group consists of the aorta and of the branches, which arise either directly or indirectly from it.

The AORTA is the great systemic arterial trunk, and lies in the cavities of the thorax and abdomen. It arises from the base of the left ventricle of the heart, and forms above the root of the left lung an arch, the *arch of the aorta*; it then descends in close relation to the thoracic spine, as the *descending thoracic aorta*; it next passes through the aortic opening in the diaphragm, enters the cavity of the abdomen, and becomes the *abdominal aorta*. In the abdomen it descends in front of the bodies of the lumbar vertebræ as low as the fourth, where it is usually described as dividing into the two terminal branches, the common iliac arteries. At the angle of bifurcation, however, a long slender artery, called the *middle sacral*, is prolonged downwards in front of the sacrum to the end of the coccyx. In animals with long tails this artery can be recognised as a direct continuation of the aorta, prolonging it downwards in front of the caudal vertebræ, whilst the iliacs are seen to be collateral branches; but in man, where the coccyx is rudimentary, and the lower limbs largely developed, the iliac arteries, which supply those limbs, are so big as to obscure the true signification of the middle sacral artery, and appear themselves to be the terminal branches of the aorta.

The ARCH OF THE AORTA springs from the base of the left ventricle on a level with the third pair of intercostal spaces

in front, and the sixth dorsal vertebra behind. It passes behind the sternum obliquely upwards and to the right, as the *ascending aorta*, or *ascending part* of the arch, to the level of the second right costal cartilage. It then changes its direction, and passes from right to left and from before backwards as the *transverse part* of the arch of the aorta. It is often stated that the transverse part of the arch reaches the left side of the spine on a level with and close to the left of the body of the second dorsal vertebra, but John Wood has pointed out that it approaches the spine at the lower border of the left side of the body of the fourth dorsal vertebra, and first touches the spine at the disc between the fourth and fifth dorsal vertebræ. Here it again changes its direction and runs vertically downwards, as the *descending part* of the arch, in close contact with the left side of the body of the fifth dorsal vertebra as far as its lower border, when it becomes the *descending thoracic aorta*.

The ascending aorta is enclosed within the bag of the pericardium, and has at its origin the three semilunar valves with the sinuses of Valsalva. The pulmonary arterial trunk is at first in front of and then to its left side; the right auricular appendage and superior cava are to its right side, and the structures going to the root of the right lung lie behind it.

The transverse part of the arch lies behind the sternum, left pleura, and left lung, and is crossed by the left phrenic, pneumogastric, and superficial cardiac nerves. It is placed in front of the trachea, œsophagus, and thoracic duct, and the left recurrent laryngeal nerve hooks round its lower surface and behind it. Its lower surface is in relation to

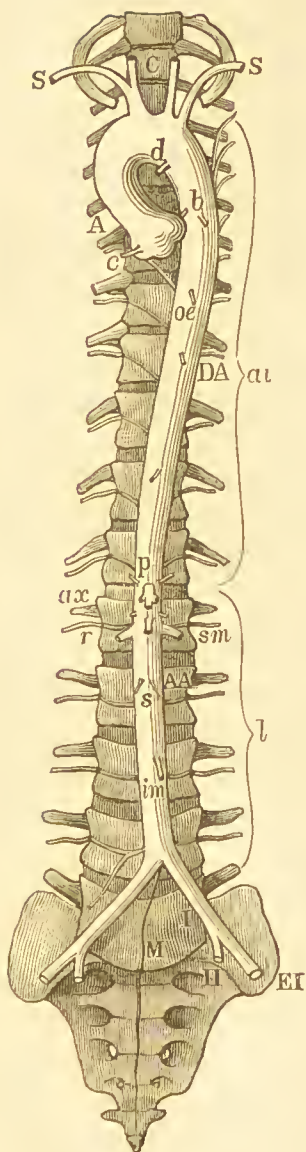


FIG. 119.—The Aorta in its relations to the spine:—A, ascending part of arch of aorta; DA, descending thoracic aorta; AA, abdominal aorta; M, middle sacral artery; S S, subclavian arteries; C, is placed on the 2nd dorsal vertebra between the two carotid arteries; I, common iliac artery; EI, external iliac; II, internal iliac artery; c, coronary artery; d, obliterated ductus arteriosus; b, bronchial artery; oe, oesophageal artery; ai, series of aortic intercostal arteries; l, series of lumbar arteries; p, between the two phrenic arteries; ax, points to the celiac axis; r, points to the two renal arteries, immediately above which are the small capsular arteries. Between the two renals is the superior mesenteric, sm; s, is placed between the two spermatic arteries; im, inferior mesenteric artery.

the pulmonary artery at its bifurcation, and has connected to it the obliterated ductus arteriosus. Its upper surface gives origin to the three arteries for the head, neck, and upper limbs, and is in relation to the left brachio-cephalic vein.

The descending part of the arch is covered by the left pleura and overlapped by the left lung, whilst the œsophagus and thoracic duct are to its right side. The root of the left lung lies in the concavity of the arch of the aorta.

The DESCENDING THORACIC AORTA is continuous with the descending part of the arch. It extends from the lower border of the left side of the body of the fifth dorsal vertebra, as far as the front of the body of the last dorsal vertebra, where it passes through the opening between the pillars of the diaphragm and becomes the abdominal aorta. It is in contact with and follows the curvature of the thoracic spine, and inclines from its left side to its anterior surface. It lies in the posterior mediastinal division of the interpleural space, and is partially covered by the left pleura. The left lung and pericardium are anterior to it. The œsophagus is at first to its right side, but crosses in front, so as to lie, immediately above the diaphragm, to its left side. The thoracic duct and greater azygos vein are to its right side, but the smaller azygos vein passes behind it.

The ABDOMINAL AORTA is directly continuous with the descending thoracic aorta. It extends from the front of the last dorsal vertebra as far as the body of the fourth lumbar, where it bifurcates into the two common iliac arteries, a little to the left of the mesial plane. It lies on the bodies of the upper four lumbar vertebræ and discs, and

is separated from the anterior abdominal wall by the stomach, pancreas, transverse colon, transverse part of duodenum, mesentery, and coils of small intestine: the splenic artery, and the splenic and left renal veins are also in relation to its anterior surface. It is to a great extent surrounded by the aortic nervous plexus of the sympathetic. The inferior vena cava, greater azygos vein, and thoracic duct are in contact with its right side. Lymphatics, veins and glands lie on the spinal column in close relation to it.

The aorta gives direct origin to numerous branches, which may be arranged in four groups.—1st, Branches for the supply of the viscera of the thorax and abdomen proper; 2d, branches for the walls of the thorax, abdomen, and pelvis; 3d, branches for the head, neck, and upper limbs; 4th, branches for the lower limbs, pelvic walls and viscera.

FIRST GROUP.—VISCERAL BRANCHES OF THE AORTA.

The branches of the aorta which supply the viscera may be arranged in two groups,—those which pass to the thoracic viscera, and those which pass to the viscera of the abdomen proper.

† The branches of the aorta which supply the Viscera of the Thorax are the coronary, the œsophageal, the bronchial, and the pericardial arteries.

• The CORONARY arteries, two in number, are the first branches of the arch of the aorta, and arise, opposite the right and left antero-lateral segments of the semilunar valve, from the wall of the aorta, where it dilates into the sinuses of Valsalva. The *right coronary* artery runs in

the auriculo-ventricular groove to the right border and posterior surface of the heart, and gives off branches to the right auricle and ventricle. A long branch descends in the posterior ventricular groove to supply the ventricles. The *left coronary* artery runs behind the pulmonary artery to the auriculo-ventricular groove, and then round the left border of the heart to its posterior surface. It supplies the left auricle and ventricle, and sends a long branch to the apex of the heart in the anterior ventricular groove. According to some observers, the mouths of the coronary arteries are covered by the opening outwards of the aortic valves during the ventricular contraction; whilst the elastic recoil of the aorta following that contraction would, it is said, not only close the aortic orifice, but drive the blood into the coronary arteries. As these arteries break up into branches in the muscular walls of the heart, a sudden turgescence of its walls would, according to Brücke and A. H. Garrod, result from the filling of these vessels, and be the cause of the dilatation of the ventricular cavities. Hyrtl and Ceradini have, however, raised important objections to this theory; they more especially urge that the valves do not close the orifices of the coronary arteries during the ventricular contraction, and that the capacity of the ventricles is diminished and not increased by the filling of these arteries.

The BRONCHIAL arteries are two in number. They may arise from the descending thoracic aorta, either by a common trunk, or independently; or the right bronchial may spring from the first aortic intercostal artery: one artery accompanies each bronchial tube, branches along with it, and supplies the tissues of the lung.

The ŒSOPHAGEAL arteries, four or five in number, arise from the descending thoracic aorta, and supply the coats of the œsophagus.

The PERICARDIAL branches are very small arteries, which arise either from the descending thoracic aorta or the œsophageal arteries, and supply the back of the bag of the pericardium, and the lymphatic glands and loose tissue of the posterior mediastinum.

The branches of the aorta which supply the Viscera of the Abdomen proper arise either singly or in pairs. The single arteries are the coeliac axis, the superior mesenteric, and the inferior mesenteric, which arise from the front of the abdominal aorta; the pairs are the two capsular, the two renal, and the two spermatic or ovarian, which arise from its sides. The single arteries supply viscera, which are either completely or almost completely invested by the peritoneum, and the veins corresponding to them are the roots of the vena portæ. The pairs of arteries supply viscera developed behind the peritoneum, and the veins corresponding to them are rootlets of the inferior vena cava.

The CÆLIAC AXIS is the first visceral branch of the abdominal aorta. It arises from the front of that vessel between the two pillars of the diaphragm, above the pancreas, and is surrounded by the solar plexus of the sympathetic. It is a thick, short artery, which almost immediately divides into the coronary, hepatic, and splenic branches.

The *Coronaria ventriculi* artery is the smallest branch, and passes upwards and to the left to the cardiac orifice of the stomach, where it subdivides into an *œsophageal* branch

for the lower end of the œsophagus, and a *gastric* branch for the coats of the stomach. The gastric branch runs along the lesser curvature, and supplies the anterior and posterior walls of the stomach.

The *Hepatic* artery passes upwards and to the left between the two layers of the gastro-hepatic omentum to



FIG. 120.—The Celiac Axis and the chief Viscera supplied by its branches.

1, Celiac axis; 2, coronary artery; 3, splenic artery; 4, its terminal branches; 5, left gastro-epiploic; 6, hepatic artery; 7, gastro-duodenal artery; 7', right gastro-epiploic; 8, pyloric branch; 9, portal vein; 10, hepatic duct; 11, cystic duct; 12, common bile duct; 13, round ligament; a, left lobe of liver; b, lobulus quadratus; c, right lobe; d, gall bladder; e, Spigelian lobe; f, cardiac orifice of stomach; g, stomach; h, pylorus; i, duodenum; k, ascending colon; l, great omentum; m, spleen.

the transverse fissure of the liver, where it terminates, by dividing into two branches—the one for the right, the

other for the left lobe of the liver. In its course it gives off *a*, the *pyloric* branch, which passes to the pyloric end of the lesser curvature of the stomach: *b*, the *gastro-duodenal* branch which descends behind the duodenum, when it divides into a *superior pancreatico-duodenal*, which supplies the pancreas and duodenum, and a *right gastro-epiploic* branch, which runs along the greater curvature of the stomach to supply branches to its anterior and posterior walls, and to the omentum: *c*, the *cystic* branch which supplies the coats of the gall bladder: *d*, the *terminal* right and left *hepatic* branches, which supply the tissues of the liver.

The *Splenic* artery is the largest branch of the *cœliac* axis. It passes to the left behind the stomach, and is lodged in a groove on the upper border of the posterior surface of the pancreas. It gives off *a*, *pancreatic* branches to supply the pancreas: *b*, *vasa brevia*, which pass to the fundus of the stomach: *c*, the *left gastro-epiploic* artery, which runs along the greater curvature of the stomach, and supplies its anterior and posterior walls and the omentum: *d*, the *terminal splenic* branches, which enter the spleen at the hilus.

The *SUPERIOR MESENTERIC* artery arises from the aorta a little below the *cœliac* axis. It lies at first behind the pancreas, then crosses in front of the duodenum, and descends between the two layers of the mesentery, inclining towards the right iliac fossa. It gives off *a*, the *inferior pancreatico-duodenal* branch, which supplies the pancreas and duodenum: *b*, the *intestinal* branches, about twelve in number, which arise from the left aspect of the artery, and descend in the mesentery to the coils of the jejunum

and ileum; in their course they bifurcate, and the branches of bifurcation of adjacent arteries inosculate to form arterial arcades, three or four series of which may be found in the mesentery; from the series next the intestine branches pass to the wall of the bowel: *c*, *ileo-colic* branch, which passes to the right iliac fossa to supply the lower end of the ileum, cæcum, and ascending colon: *d*, *right colic* branch, which runs to the ascending colon to supply it: *e*, the *middle colic* branch, which passes between the layers of the meso-colon to the transverse colon to supply it. All these colic arteries bifurcate, anastomose, and form arterial arcades after the manner of the branches to the small intestine.

The INFERIOR MESENTERIC artery arises from the aorta a short distance above its bifurcation. It lies behind the peritoneum covering the posterior wall of the abdomen, and passes downwards to the left iliac fossa, where it enters the meso-rectum, and takes the name of *superior hæmorrhoidal artery*, and supplies the coats of the rectum. It gives off *a*, the *left colic* branch, which runs to the descending colon to supply it: *b*, *sigmoid* branch, which runs between the two layers of the meso-colon to the sigmoid flexure to supply it; these branches bifurcate, anastomose, and form arterial arcades as on the right side.

The arteries which supply the coats of the alimentary tube from the œsophagus to the rectum, anastomose freely with each other in the wall of the tube, or in its mesenteric attachment, and the anastomoses are usually by the formation of arches or loops between adjacent branches. Thus the œsophageal branches of the aorta anastomose with each other and with the œsophageal branch of the

coronary artery, which again anastomoses with the gastric branch of the same artery. This gastric branch anastomoses along the lesser curvature of the stomach with the pyloric branch of the hepatic. Along the greater curvature the left gastro-epiploic of the splenic anastomoses with the right gastro-epiploic of the gastro-duodenal branch of the hepatic, and in the walls of the stomach, branches from these arteries of the curvatures anastomose with each other and with the vasa brevia of the splenic. Along the curve of the duodenum, the superior pancreatico-duodenal of the gastro-duodenal of the hepatic anastomoses with the inferior pancreatico-duodenal of the superior mesenteric. The intestinal branches of the superior mesenteric anastomose not only with each other in the series of arterial arcades already described, but with the inferior pancreatico-duodenal and ileo-colic branches of the same artery. In the large intestine the ileo-colic anastomoses with the right colic, and the right colic with the middle colic branch of the superior mesenteric. The middle colic, anastomoses with the left colic of the inferior mesenteric, the left colic with the sigmoid, and the sigmoid with the superior hæmorrhoidal artery. The superior hæmorrhoidal anastomoses in the coats of the rectum, near its lower end, with the middle hæmorrhoidal branch of the internal iliac and the inferior hæmorrhoidal branch of the pudic. Through this chain of anastomoses, provision is made for equalizing the distribution of blood to the coats of the several divisions of the alimentary canal, and of providing secondary channels for the conveyance of blood to any division, in the event of the proper artery for that part being obstructed,—a point of great importance in connection with

the glandular or secreting function of the alimentary mucous membrane.

The CAPSULAR arteries, small in size, arise from the sides of the aorta above the renal arteries, and run outwards, to end in the supra-renal capsules.

The RENAL arteries arise from the sides of the aorta, and pass outwards, one to each kidney. They send branches to the supra-renal capsule and ureter. In the substance of the kidney they give off small *perforating* branches, which pierce the capsule of the kidney, and are distributed in the surrounding fat.

The SPERMATIC arteries are two long slender arteries, which arise from the aorta close to the renal arteries. They descend one on each side, behind the peritoneum, to the internal or deep abdominal ring, where each comes into relation with the vas deferens, and assists in forming the spermatic cord, which passes into the scrotum to the testicle. The corresponding arteries in the female, called the OVARIAN, do not leave the abdomen ; they supply the ovaries.

SECOND GROUP.—PARIETAL BRANCHES OF THE AORTA.

The branches of the aorta which supply the walls of the thorax, abdomen, and pelvis, are the intercostal, the lumbar, the phrenic, and the middle sacral arteries.

The INTERCOSTAL arteries arise from the back of the thoracic aorta, and are usually ten pairs. They run along the sides of the vertebral bodies as far as the commencement of the intercostal spaces, when each divides into a *dorsal* and a *proper intercostal* branch ; the dorsal branch passes to the back of the thorax to supply the deep muscles

of the spine, and gives a *spinal* branch to the spinal cord through the inter-vertebral foramen. The proper intercostal branch runs outwards in the intercostal space close to the lower border of the upper of the two ribs, and gives off a collateral branch which runs parallel to the upper border of the lower rib; they supply the intercostal muscles, and the lower pairs of intercostals also give branches to the diaphragm and wall of the abdomen.

The LUMBAR arteries arise from the back of the abdominal aorta, and are usually four pairs. They run along the sides of the lumbar vertebræ, under cover of the psoas muscle, and divide into a *dorsal* branch, which supplies the

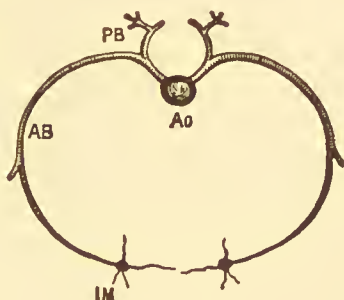


FIG. 121.—Diagram of a pair of Intercostal arteries. Ao, the aorta transversely divided, giving off at each side an intercostal artery; PB, the posterior or dorsal branch; AB, the anterior or proper intercostal branch; IM, a transverse section through the internal mammary artery, the anterior intercostal branch of which anastomoses with the aortic intercostal.

deep muscles of the back of the loins, and an *abdominal* branch, which runs outwards behind the quadratus lumborum muscle to supply the wall of the abdomen. From the dorsal branch, a small *spinal* branch passes through the inter-vertebral foramen into the spinal canal to supply the nerve roots, membranes, and vertebræ. The distribution of the lumbar and intercostal arteries exhibits a transversely-segmented arrangement of the vascular system in the walls of the abdomen and thorax, similar to the transversely-segmented arrangement of the bones, muscles, and nerves observed in these localities, especially in the thoracic region.

The PHRENIC arteries, two in number, arise from the aorta close to the crura of the diaphragm ; the right phrenic passes behind the inferior cava, the left behind the œsophagus, to supply the diaphragm ; they also give branches to the supra-renal capsules.

The MIDDLE SACRAL artery, as already stated, is rather the continuation of the aorta downwards from the place of bifurcation than a branch of that vessel. As it runs down the front of the sacrum it gives transverse branches to the sacral wall of the pelvis.

In close connection with the terminal twigs of the middle sacral artery is a body, about the size of a small pea, named by Luschka the *coccygeal gland*. This body, now more usually called the *coccygeal body*, is not a gland, but, as Julius Arnold pointed out, is composed principally of the dilated and tortuous twigs of the middle sacral artery, the middle or muscular coat of which is greatly thickened. But, in addition, a laminated arrangement of cells is found within the dilatations. The body is invested by connective tissue in which nerve cells are embedded. Branches of the ganglion impar of the sympathetic pass to the coccygeal body.

Important anastomoses take place in the walls of the thorax and abdomen between the parietal branches of the aorta and branches of other arteries which pass to the parietes. If we go from the upper to the lower parts of the walls of the chest and belly, the following arteries may be seen to run from behind forwards, the superior intercostal branch of the subclavian in the first and second intercostal spaces ; the intercostal branches of the aorta in the other intercostal spaces ; the lumbar branches of the aorta in the muscular

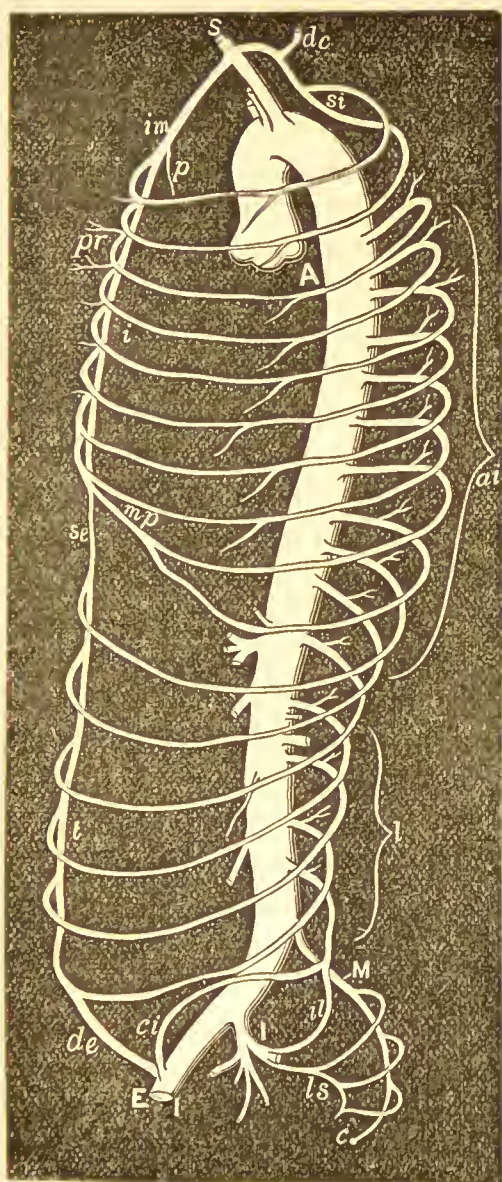


FIG. 122.—Arteries of the left wall of the Thorax and Abdomen. *A*, aorta; *E*, external iliac; *I*, internal iliac; *M*, middle sacral artery; *S*, subclavian; *si*, superior intercostal; *dc*, deep cervical; *im*, internal mammary; *p*, its phrenic; *pr*, its perforating; *i*, its anterior intercostal; *mp*, its musculo-phrenic, and *se*, its superior epigastric branch; *ai*, aortic intercostals; *l*, lumbar arteries; *de*, deep epigastric; *t*, its transverse branches; *ci*, circumflex iliac artery; *il*, ilio-lumbar artery; *ls*, lateral sacral artery; *c*, coccygeal body.

wall of the abdomen, and the ilio-lumbar branch of the internal iliac artery in the iliac fossa. These inosculate with the branches of three arteries which run from before backwards in the same parietes. Thus the internal mammary branch of the subclavian artery descends behind the cartilages of the ribs, and gives off the anterior intercostal branches, which run outwards to join the superior intercostal and aortic intercostals in the thoracic wall; also the musculo-phrenic branch which inosculates in the diaphragm with the aortic intercostals and the phrenic branches of the aorta; whilst the internal mammary terminates in the anterior wall of the abdomen by inosculating with the deep epigastric artery. From the external iliac artery arise two branches—the deep epigastric and deep circumflex iliac. The deep epigastric ascends behind the rectus abdominis, inosculates with the superior epigastric of the internal mammary, and with the lower intercostal and lumbar branches of the aorta. The deep circumflex iliac runs outwards along the line of the iliac crest, and inosculates with the lumbar arteries and the ilio-lumbar of the internal iliac. In the region of the pelvis the transverse branches of the middle sacral artery inosculate with the lateral sacral branches of the internal iliac.

The statement has frequently been made that the visceral and parietal branches of the aorta do not anastomose with each other, but injections which I made some years ago proved that, both in the thoracic and abdominal cavities, slender anastomosing communications exist between the two sets of branches. In the abdominal cavity a wide meshed plexus of small arteries, which I have named the *sub- or extra-peritoneal* plexus, lies in the fat outside the

peritoneum. On the one hand, it communicates with the perforating branches of the renal arteries and with slender branches of the capsular, spermatic, colic, and pancreatic arteries, and in the region of the diaphragm with the capsular branches of the hepatic artery. On the other hand, it communicates with the phrenic arteries, the lower intercostals, the lumbar branches of the aorta, and with the ilio-lumbar, circumflex iliac, and epigastric branches of the iliac arteries, which also go to the wall of the abdomen. In the pelvis also the visceral superior hæmorrhoidal artery anastomoses with the middle and lateral sacral arteries. The extra-peritoneal plexus supplies the gangliated cord of the sympathetic and the fat and lymphatic glands lying outside the peritoneum, and it also gives origin to *vasa vasorum* for the coats of the aorta and vena cava. This plexus may, when the visceral branches of the aorta are obstructed, aid in an important manner in carrying on the circulation. In a subject examined by J. Chiene, in the dissecting-room of the University of Edinburgh, where the celiac axis and the superior and inferior mesenteric arteries were obliterated at their origins, the blood flowed from the parietal arteries, into these visceral arteries and the viscera they supplied, through a great enlargement of the arteries of the extra-peritoneal plexus. In the thoracic cavity a similar plexus, which I have named the *extra-pleural* plexus, lies between the pleura and pericardium; it communicates, on the one hand, with the phrenic and mediastinal branches of the internal mammary arteries, and on the other passes in front of the root of the lung to join the bronchial system of vessels. Another portion of this plexus joins, on the one hand, the intercostal arteries

near the dorsal vertebræ, and on the other passes to the lung behind its root.

THIRD GROUP.—BRANCHES OF THE AORTA FOR THE HEAD,
NECK, AND UPPER LIMBS.

The branches for the head, neck, and upper limbs arise as three large arteries from the upper surface of the transverse part of the aortic arch; they are named in the order in which they arise from right to left, *arteria innominata*, left common carotid, and left subclavian.

The *ARTERIA INNOMINATA*, or *BRACHIOCEPHALIC* artery, is the largest branch of the arch of the aorta, and springs from the commencement of its transverse part. It passes upwards and to the right, to the root of the neck, on a level with the right sterno-clavicular articulation, and then divides into the right common carotid and the right subclavian artery. It lies in the upper part of the chest behind the manubrium sterni and in front of the trachea. The right brachio-cephalic vein and right pleura are to its right, the left common carotid artery is to its left, and the left brachio-cephalic vein crosses between it and the sternum. It gives off, as a rule, no collateral branches.

Subclavian System of Arteries.

This system consists of the large artery of supply for the upper extremity, and of the branches, which arise either directly or indirectly from it. This artery bears different names in its course. It is called *subclavian*, as it passes across the root of the neck and under the clavicle;

when it enters the armpit, it becomes the *axillary* artery ; by that name it extends as far as the posterior fold of the axilla, when it enters the upper arm, takes the name of *brachial* or *humeral* artery, and courses as far as the bend of the elbow, where it bifurcates into the *radial* and *ulnar* arteries.

The SUBCLAVIAN artery arises on the right side at the bifurcation of the innominate artery ; but on the left side directly from the arch of the aorta, being the last of the three branches of the transverse part of the arch. The right subclavian arches across the root of the neck, and passing behind the clavicle and subclavius muscle, reaches the outer border of the first rib, where it becomes the axillary artery. The left subclavian has to ascend through the upper part of the thorax into the neck, before it arches across the root of the neck. In its course each subclavian artery goes behind the scalenus anticus muscle, so that it is customary to divide this artery into three parts ; a first part internal to the scalenus, a second part behind that muscle, a third part to its outer side.

The relations of the first part of the subclavian are not the same on the right and left sides, owing to the difference in origin of the two vessels. The first part of the left subclavian is longer than that of the right ; it is overlapped by the left pleura and lung, and is crossed by the left innominate vein ; it lies in front of the œsophagus and thoracic duct ; whilst to its right side are the trachea, left common carotid artery, left vagus, and recurrent laryngeal nerves. The first part of the right subclavian is covered by the platysma, sterno-mastoid, sterno-hyoid and sterno-thyroid muscles, and by the cervical fascia ; it is crossed by

the vertebral and internal jugular veins, the cardiac branches of the sympathetic and the right vagus nerve. The right recurrent laryngeal nerve hooks behind it. The right subclavian vein lies below it, and the right pleura is below and posterior to it.

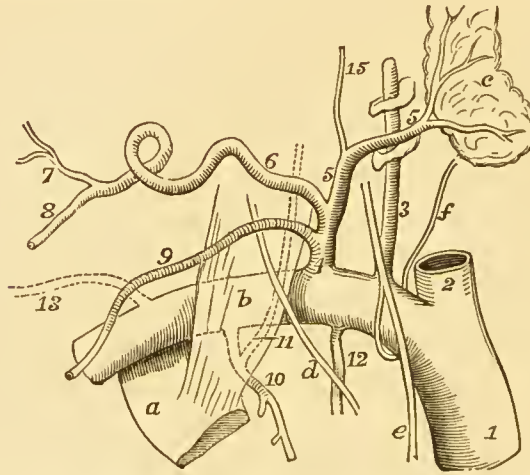


FIG. 123.—The Right Subclavian Artery and its Branches.

1, Innominate artery; 2, common carotid; 3, vertebral branch of subclavian; 4, thyroid axis; 5, inferior thyroid branch; 6, transversalis colli; 7, superficialis colli; 8, posterior scapular; 9, supra scapular; 10, superior intercostal; 11, deep cervical; 12, internal mammary; 13, in dotted outline shows the occasional origin of the posterior scapular from the third part of the subclavian; 15, ascending cervical artery. *a*, 1st rib; *b*, scalenus anticus; *c*, thyroid gland; *d*, phrenic nerve; *e*, pneumo-gastric nerve; *f*, recurrent laryngeal nerve.

The relations of the second and third parts of the subclavian arteries are the same on both sides. The second part lies upon the scalenus medius, and has the scalenus anticus, sterno-mastoid, cervical fascia, and platysma superficial to it; it is separated by the scalenus anticus from the subclavian vein and phrenic nerve; above it are the nervous cords of the brachial plexus, and below is the pleura.

The third part of the subclavian artery lies partly in the supra-clavicular triangle—a region bounded by the pos-

terior belly of the omo-hyoid, the sterno-mastoid muscle, and the clavicle—and partly under cover of the clavicle and subclavius muscle. It is covered by the skin, platysma, and cervical fascia, and is crossed by the external jugular vein, the nerve to the subclavius, and the descending cutaneous branches of the cervical plexus. It rests on the scalenus medius and the grooved upper surface of the first rib. The cords of the brachial plexus are above and the subclavian vein below it. From the subclavian artery branches arise in the following order :—

a. Vertebral, which arises from the first part of the artery. It enters the foramen at the root of the transverse process of the sixth cervical vertebra, ascends through the corresponding foramina in the vertebræ above, lies in a groove on the arch of the atlas, pierces the dura mater, and enters the skull through the foramen magnum, where it joins its fellow to form the *basilar* artery. It is accompanied by vaso-motor branches from the inferior cervical ganglion of the sympathetic, and by the vertebral vein, and in its ascent through the series of foramina, it lies in front of the cervical nerves. It gives off *muscular* branches to the deep muscles of the neck : *spinal* branches, which enter the intervertebral foramina and pass to the spinal cord : a *posterior spinal* branch, arises on a level with the medulla oblongata, and descends on the back of the cord to anastomose with the spinal branches which enter the intervertebral foramina : an *anterior spinal* branch arises on the same level, descends in front of the cord, anastomoses with its fellow, and forms the *anterior median* artery of the cord, which artery anastomoses in its descent with the spinal branches from the vertebral, inferior thyroid, intercostal and

lumbar arteries, so as to form a long slender artery, situated in front of the cord in its entire length, which supplies the cord and the pia mater: *meningeal* branches to the dura mater: an *inferior cerebellar* branch to the under surface of the cerebellum. The *Basilar* artery, formed by the junction of the two vertebrals, extends from the lower to the upper border of the pons Varolii; it gives off collaterally *transverse* branches to the pons: *auditory* branches which accompany the portio mollis to the internal ear: *inferior cerebellar* branches to the under surface of the cerebellum: whilst it breaks up into four terminal branches, viz., two *superior cerebellar* to the upper surface of the cerebellum, and two *posterior cerebral* which supply the convolutions on the tentorial aspect of the temporo-sphenoidal lobes, those of the occipital lobes, and the posterior convolutions of the parietal lobes of the cerebrum: *perforating* branches pass from the posterior cerebral artery to the locus perforatus posterior. The third cranial nerve on each side appears between the superior cerebellar and posterior cerebral arteries.

b. Thyroid Axis, a short branch, which immediately divides into the *inferior thyroid*, the *supra-scapular*, and the *transversalis colli* branches. The *Inferior Thyroid* ascends on the longus colli muscle, and then turns inwards behind the sheath of the carotid vessels and the gangliated cord of the sympathetic to be distributed to the thyroid body; it gives off an *ascending cervical* branch to the muscles of the neck, which also sends small *spinal* branches to the spinal cord: a *laryngeal* branch which accompanies the inferior laryngeal nerve to the larynx: *oesophageal* branches to the oesophagus. The *Supra-scapular* runs outwards behind the sterno-mastoid muscle and the clavicle,

reaches the upper border of the scapula, and passes over the supra-scapular ligament to the dorsum of the scapula, where it ramifies in the supra and infra spinous fossæ, and supplies the muscles on the dorsum scapulæ. The *Transversalis Colli* passes outwards behind the sterno-mastoid and above the clavicle ; it then goes under cover of the trapezius, and divides into the *superficial cervical* and *posterior scapular* branches ; the superficial cervical ends in the trapezius and levator scapulæ muscles ; the posterior scapular runs parallel to the posterior border of the scapula, supplies the muscles attached to that border, and gives branches to the dorsal and ventral surfaces of the scapula. The *transversalis colli* artery varies in its arrangement in different individuals ; it not unfrequently ends in the trapezius, and represents in its distribution the superficial cervical branch ; in these cases the posterior scapular branch arises directly from the subclavian.

c. Internal Mammary arises from the lower surface of the first part of the subclavian, passes into the thorax behind the cartilage of the first rib, and descends behind the internal intercostal muscles and costal cartilages as far as the sixth intercostal space, where it divides into the *musculo-phrenic* and *superior epigastric* branches. The costal pleura lies immediately behind the upper part of the artery, but its lower part is separated from the pleura by the triangularis sterni muscle. In its course the following branches arise :—*arteria comes nervi phrenici*, which accompanies the phrenic nerve to the diaphragm : *mediastinal* branches to the thymus gland, pericardium, and areolar tissue of the mediastinal space : *perforating* branches, which pierce the internal intercostal and greater

pectoral muscles, and supply the skin of the front of the chest; the second and third perforating arteries pass to the mammary gland: *anterior intercostals* run outwards in the upper five or six intercostal spaces, and inosculate with the aortic intercostals: *musculo-phrenic*, one of the two terminal branches, runs outwards along the line of origin of the diaphragm, and assists in supplying that muscle: *superior epigastric*, the other terminal branch, descends in the wall of the abdomen in the sheath of the rectus, and supplies that muscle.

d. Superior Intercostal arises from the back of the second part of the subclavian; it descends into the back of the cavity of the chest in front of the neck of the first rib, and ends in two branches, one for the first, the other for the second intercostal space. Before it enters the chest it gives off the *deep cervical* artery, which passes backwards between the transverse process of the seventh cervical vertebra and the neck of the first rib, and then ascends on the back of the neck between the complexus and semispinalis colli muscles to supply them. It is equivalent to the dorsal branch of an aortic intercostal, and sometimes arises directly from the subclavian.

The branches, which arise either directly or indirectly from the subclavian artery, may be arranged, according to their distribution to the parts which they supply, in three groups:—

1st. To neck, thyroid gland, windpipe, brain, and spinal cord: vertebral, inferior thyroid, ascending cervical, superficial cervical, deep cervical arteries;

2d. To walls of trunk: internal mammary, superior intercostal arteries;

3d. To scapular region : transversalis colli, supra-scapular arteries.

The AXILLARY artery is the direct continuation of the subclavian ; it commences at the outer border of the first rib and passes through the axilla, in close relation to the outer wall, as far as the lower border of the tendon of the teres major muscle, where it becomes the brachial artery. In this course it lies in relation to the inner aspect of the head and upper part of the shaft of the humerus. It is covered, in addition to the skin and fasciæ, by the costo-coracoid membrane, pectoralis major and minor muscles, but where it lies on the teres major it passes from under cover of the greater pectoral. It is in relation behind to the serratus magnus, subscapularis, latissimus dorsi, and teres major muscles. The axillary vein lies to its inner side, and it is crossed at its upper end by the cephalic vein. The axillary plexus of nerves is at first to its outer side ; then the plexus is disposed with one cord to the outer side of the artery, another to the inner side, and a third behind it ; whilst lower down the branches arising from these cords are so arranged about the artery that the median and musculo-cutaneous nerves are to its outer side ; the ulnar, internal cutaneous and lesser internal cutaneous are to its inner side, and the circumflex, musculo-spiral, and subscapular are behind it.

The branches of the axillary artery are as follows :—

a. *Short Thoracic* arises above the pectoralis minor, and runs inwards to the upper part of the lateral wall of the chest.

b. *Thoracic Axis* arises close to the upper border of the pectoralis minor, and almost immediately divides into the

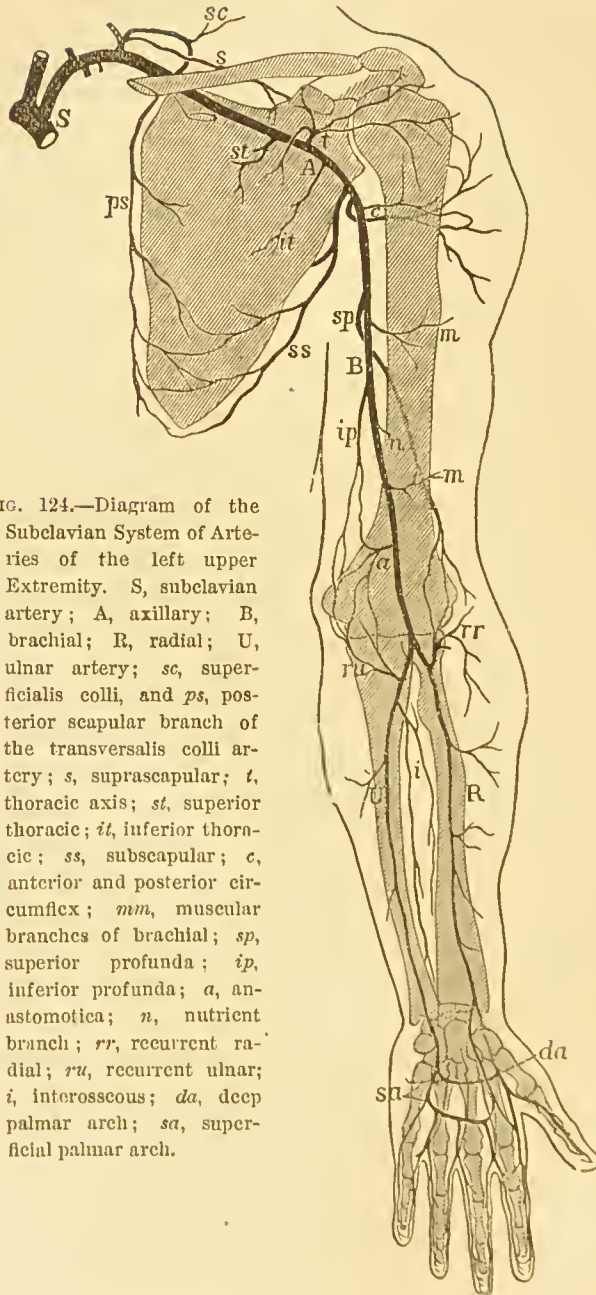


FIG. 124.—Diagram of the Subclavian System of Arteries of the left upper Extremity. S, subclavian artery; A, axillary; B, brachial; R, radial; U, ulnar artery; *sc*, superficialis colli, and *ps*, posterior scapular branch of the transversalis colli artery; *s*, suprascapular; *t*, thoracic axis; *st*, superior thoracic; *it*, inferior thoracic; *ss*, subscapular; *c*, anterior and posterior circumflex; *mm*, muscular branches of brachial; *sp*, superior profunda; *ip*, inferior profunda; *a*, anastomotica; *n*, nutrient branch; *rr*, recurrent radial; *ru*, recurrent ulnar; *i*, interosseous; *da*, deep palmar arch; *sa*, superficial palmar arch.

following branches ; *acromial thoracic*, which passes outwards to the deltoid and the region of the acromion : *humeral thoracic*, which descends, at the side of the cephalic vein, between the deltoid and greater pectoral muscles to which it gives branches : *pectoral thoracic*, which supplies the two pectoral muscles : *clavicular thoracic*, which supplies the subclavius muscle.

c. Long Thoracic, or *External Mammary*, runs parallel to the lower border of the lesser pectoral muscle to the lateral wall of the chest, and in woman supplies the mammary gland.

d. Alar Thoracic, a short branch to the fat and lymphatic glands of the axilla : it sometimes arises from the subscapular or long thoracic arteries.

e. Subscapular arises opposite the lower border of the subscapularis, along which it runs to the inferior angle of the scapula and lateral wall of the chest ; it supplies the serratus magnus and the muscles of the posterior wall of the axilla : it gives off a large *dorsal* branch, which turns round the axillary border of the scapula, in the triangular space bounded by the teres minor, teres major, and long head of the triceps, which branch ramifies on the dorsum of the scapula to supply the teres minor and infra-spinatus.

f. Anterior Circumflex, a small branch, which runs outwards in front of the humerus to the bicipital groove, where it sends a branch along with the tendon of the biceps to the shoulder joint, and terminates in the deltoid muscle.

g. Posterior Circumflex, a large branch, which winds round the back of the humerus, along with the circumflex nerve, in the quadrilateral space bounded by the teres minor, teres major, long head of the triceps and shaft of

the humerus : it ends in the deltoid muscle, for which it is the principal artery of supply.

The branches of the axillary artery may be arranged according to their distribution in three groups :—

1st. To walls of thorax : short thoracic, long thoracic, pectoral thoracic, terminal branches of subscapular artery.

2d. To scapulo-humeral region : acromio-thoracic, clavicular thoracic, humeral thoracic, anterior and posterior circumflex, and dorsal branch of subscapular artery.

3d. To fat and glands of axilla : alar thoracic artery.

The branches to the walls of the thorax anastomose with the superior intercostal of the subclavian, the aortic intercostals and the anterior intercostals of the internal mammary. The branches to the scapulo-humeral region inosculate with the posterior scapular and supra-scapular branches of the subclavian. Both series of inosculations enlarge, and form secondary channels for the conveyance of blood to the upper limb, when the third part of the subclavian artery is tied.

The BRACHIAL or HUMERAL artery is the direct continuation of the axillary. It commences at the lower border of the tendon of the teres major, and passes down the upper arm to a little below the bend of the elbow, where it divides into two terminal branches, the radial and ulnar arteries. In this course it lies at first to the inner side of the shaft of the humerus, but lower down it inclines to the front of that bone. It is covered by the skin and fasciæ, and at the bend of the elbow it is crossed by the thin tendon of the biceps, which is inserted into the fascia of the fore arm. It is in relation behind to the long head of the triceps, but is separated from it by the musculo-spiral nerve

and superior profunda artery, whilst lower down it rests on the tendon of insertion of the coraco-brachialis, and on the brachialis anticus muscle. At first the coraco-brachialis, and then the inner border of the biceps, are to its outer side, and in muscular arms it is overlapped by the latter muscle, the inner border of which forms a definite guide to the position of the artery. It is accompanied by two venæ comites; and the basilic vein, separated by the brachial aponeurosis, is superficial to it, whilst at the bend of the elbow the median basilic vein is separated from it by the thin tendon of the biceps. The median nerve is at first to its outer side, then crosses over it, but at and immediately above the bend of the elbow it is to its inner side.

Not unfrequently the brachial artery divides into the radial and ulnar arteries in the upper arm, and the division may in some cases take place as high as the axilla. In those instances in which a supra-condyloid process and foramen are developed (p. 41), the brachial artery and median nerve are deflected from their usual course to pass through the foramen, though occasionally the foramen only transmits the median nerve.

The branches of the brachial artery are as follows :—

a. Muscular branches pass outwards from the brachial artery to supply the biceps, coraco-brachialis, and brachialis anticus muscles.

b. Superior Profunda arises from the upper portion of the brachial; it winds downwards, backwards, and outwards, along with the musculo-spiral nerve in the musculo-spiral groove of the humerus, passes between the heads of the triceps, then pierces the external inter-muscular septum of the upper arm to reach the interval between the

brachialis anticus and supinator longus muscles, and to end at the outer side of the elbow ; it is the artery of supply for the triceps.

c. Inferior Profunda arises opposite the coraco-brachialis, and descends along with the ulnar nerve to the interval between the inner condyle of the humerus and the olecranon.

d. Anastomotica arises from one to two inches above the elbow, and divides into two branches—the smaller branch descends on the brachialis anticus in front of the elbow ; the larger pierces the internal inter-muscular septum, and reaches the interval between the inner condyle and the olecranon.

e. Nutrient enters the nutrient canal in the shaft of the humerus to supply the medulla of the bone.

The branches of the brachial artery may be arranged according to their distribution in four groups :—

1st. To muscles alone : muscular branches.

2d. To muscles and region of elbow : superior profunda, inferior profunda, anastomotica arteries.

3d. To bone : nutrient artery.

4th. Terminal : radial and ulnar arteries.

The ULNAR artery, the larger of the two terminal branches of the brachial extends down the ulnar side of the front of the fore arm to the wrist, where it crosses in front of the anterior annular ligament, and reaches the palm of the hand ; it then curves outwards towards the thumb, and anastomoses with the superficial volar and radial index branches of the radial artery to form the SUPERFICIAL PALMAR ARTERIAL ARCH. In the fore arm the ulnar artery passes at first behind the pronator teres, flexor

carpi radialis, palmaris longus, and flexor sublimis digitorum muscles, and then descends, covered only by the skin and fasciæ, close to the radial border of the flexor carpi ulnaris, as far as the radial side of the pisiform bone, when it passes under cover of the palmaris brevis muscle and the palmar fascia and forms the superficial palmar arch. It rests when in the fore arm for a short distance on the brachialis anticus, and then on the flexor profundus digitorum; at the wrist it lies on the anterior annular ligament; in the hand on the flexor tendons of the fingers, and the branches of the median and ulnar nerves. It is accompanied by the deep ulnar veins. The median nerve is separated from the commencement of the artery by the deep head of origin of the pronator teres. About the junction of the upper and middle thirds of the fore arm the ulnar nerve comes into relation with the artery, and passes along with it to the hand, the nerve being close to the inner side of the artery.

The ulnar artery in the fore arm gives origin to the following branches :—

a. Anterior Ulnar Recurrent arises close to the origin of the ulnar, and ascends in front of the brachialis anticus to anastomose with the anastomotie artery.

b. Posterior Ulnar Recurrent arises close to the anterior, and passes upwards and backwards to the interval between the inner condyle and olecranon. It and the anterior recurrent supply the muscles in front, and to the inner side of the elbow joint.

c. Interosseus is the largest branch of the ulnar, and arises high in the fore arm; after a course of about an inch it divides into the anterior and posterior interosseous branches. The *anterior interosseous* artery passes down the

fore arm, lying on the interosseous membrane, and between the flexor longus pollicis and flexor profundus digitorum muscles, as far as the pronator quadratus muscle, when it divides into two terminal branches—one to reach the front of the carpus, the other and larger pierces the interosseous membrane to reach the back of the carpus. It is accompanied, when in front of the interosseous membrane, by the anterior interosseous branch of the median nerve. It supplies *muscular* branches to the deep muscles of the fore arm; a *median* branch, which is occasionally an artery of considerable size, accompanies and supplies the median nerve, and descends with it to the palm of the hand; *nutrient* branches, to enter the foramina in the shafts of the radius and ulna. The *posterior interosseous* artery passes backwards through the interosseous space, and between the supinator brevis and extensor ossis metacarpi pollicis muscles to supply the muscles on the back of the fore arm; it gives off the *posterior interosseous recurrent* branch, which ascends under cover of the anconeus to the interval between the outer condyle and the olecranon.

d. Muscular branches to muscles of fore arm.

e. Posterior Ulnar Carpal, a small and inconstant branch, arises opposite the wrist, and forms an arch with the posterior radial carpal on the back of the carpus, and supplies the articulations.

f. Anterior Ulnar Carpal, also small and inconstant, is covered by the flexor tendons, and forms an arch with the anterior radial carpal on the front of the carpus, the articulations of which it supplies.

The palmar portion of the ulnar artery, or superficial palmar arch, gives origin to the following branches :—

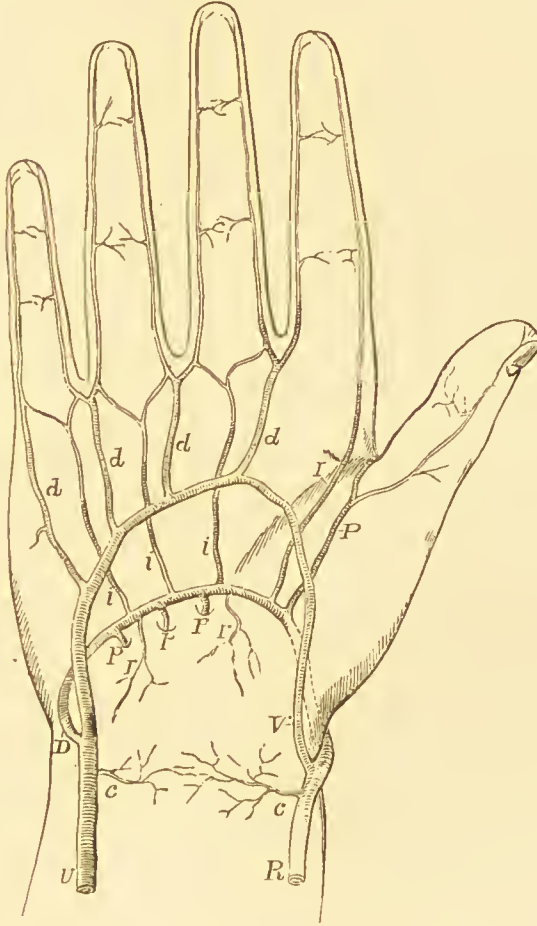


FIG. 125.—Diagram of the Arteries of the Hand.

R, radial artery; V, superficial volar; P, arteria magna pollicis; I, artery of the radial side of the index; U, ulnar; D, its deep branch; c, c, ulnar and radial anterior carpal branches; d, d, d, d, digital branches from the superficial palmar arch; i, i, i, interosseous branches from the deep arch; p, p, p, perforating branches; r, r, recurrent branches.

g. Profunda or *deep* branch arises just beyond the pisiform bone, and dips between the flexor brevis and ab-

ductor minimi digiti into the deep part of the palm, where it inosculates with the radial artery to form the deep palmar arch ; it is accompanied by the deep branch of the ulnar nerve.

h. Recurrent branches, small and inconstant in number, run upwards towards the anterior annular ligament.

i. Digital branches, four in number, arise from the convexity of the arch ; the *first* runs down the ulnar border of the little finger ; the *second* runs to the cleft between the little and ring fingers, bifurcates, and the branches of bifurcation supply the contiguous borders of those fingers ; the *third* goes to the cleft between the ring and middle, and the *fourth* to the cleft between the middle and index, where they bifurcate and supply the contiguous borders of their respective digits. Opposite the middle of the ungual phalanx the digital arteries from the two borders of each finger converge, anastomose and form an arch on the palmar surface of the phalanx, from which small branches arise to supply the tip of the finger.

The superficial palmar arch is subject to variations in its formation ; the ulnar may not be joined by the superficialis volæ, or by the index branch of the radial artery, or the ulnar artery may be relatively small, and the branches of the radial artery may take a larger share in the formation of the arch.

The branches which arise either directly or indirectly from the ulnar may be arranged according to their distribution in six groups :—

- 1st. To muscles of fore arm : muscular and interosseous.
- 2d. To bones : nutrient artery.

3*d.* To elbow joint : anterior and posterior ulnar recurrent, posterior interosseous recurrent artery.

4*th.* To wrist joint : anterior and posterior ulnar carpal.

5*th.* To muscles of hand : deep ulnar artery.

6*th.* To digits : the four digital arteries.

The RADIAL artery extends down the radial side of the front of the fore arm, turns round the outer side of the wrist, below the styloid process of the radius, to the back of the hand ; then passes between the first and second metacarpal bones to the palm, across which it runs as far as the fourth metacarpal bone, where it joins the deep branch of the ulnar, and forms the DEEP PALMAR ARTERIAL ARCH. In the fore arm the radial artery is placed so near the surface that it is covered only by the skin and fasciæ, though in muscular arms the supinator longus overlaps it. It lies on or over the radial tendon of the biceps, the supinator brevis, pronator teres, radial origin of the flexor sublimis, flexor pollicis longus, and pronator quadratus muscles, and on the lower end of the radius. To its outer side is the supinator longus ; to its inner side the pronator teres in the upper, and the flexor carpi radialis in the lower part of its course ; as it lies between the tendons of the supinator longus and flexor carpi radialis, its pulsations can be readily felt in the living body. It is accompanied by the deep radial veins, and the radial nerve is close to its outer side in the middle third of the fore arm.

At the wrist and back of the hand the radial artery is crossed by the three extensor tendons of the thumb, and rests on the external lateral ligament of the wrist and the back of the carpus.

As it enters the palm it goes between the two heads of

the abductor indicis muscle, and, as the deep palmar arch it is covered by the flexor brevis pollicis and the flexor tendons of the fingers ; it rests on the interossei muscles and the metacarpal bones.

The radial artery in the fore arm gives origin to the following branches :—

a. Radial Recurrent arises just below the elbow, and ascends in front of the brachialis anticus to the interval between that muscle and the supinator longus.

b. Muscular branches to muscles of fore arm.

c. Anterior Radial Carpal arises close to the wrist, and forms with the anterior ulnar carpal an arch in front of the carpal joints.

d. Superficial Volar arises close to the wrist, and descends to the ball of the thumb, where it supplies the muscles and inosculates with the ulnar artery to assist in forming the superficial palmar arch.

At the wrist and back of the hand arise—

e. Posterior Radial Carpal, which runs across the back of the wrist, and forms an arch with the posterior ulnar carpal ; from this arch arise the *dorsal interosseous* branches for the third and fourth metacarpal spaces.

f. 1st Dorsal Interosseous descends superficial to the second dorsal interosseous muscle as far as the cleft between the index and middle fingers.

g. Dorsal branches for Thumb, two in number, descend on the radial and ulnar borders of the back of the metacarpal bone of the thumb.

h. Dorsal branch for Index descends on back of metacarpal bone of index finger.

In the palm of the hand the radial artery and the deep arch which it forms give origin to—

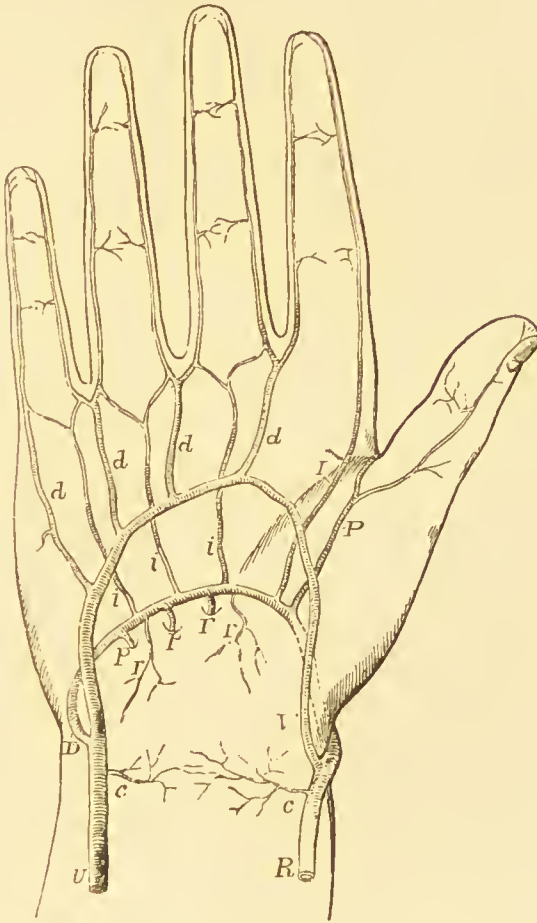


FIG. 126.—Diagram of the Arteries of the Hand.

R, radial artery; V, superficial volar; P, arteria magna pollicis; I, artery of the radial side of the index; U, ulnar; D, its deep branch; c, c, ulnar and radial anterior carpal branches; d, d, d, digital branches from the superficial palmar arch; i, i, i, interosseous branches from the deep arch; p, p, p, perforating branches; r, r, recurrent branches.

i. *Arteria Magna Pollicis*, which runs close to the metacarpal bone of the thumb, and divides into two *digital*

branches, one for each of the two borders of the thumb on its palmar aspect.

j. Arteria Radialis Indicis is the *digital* branch for the radial side of the index finger. It frequently inosculates with the ulnar artery to assist in forming the superficial palmar arch.

k. Recurrent branches run to the front of the wrist to supply the synovial membrane enveloping the flexor tendons.

l. Perforating branches pass between the heads of the three inner dorsal interossei muscles to the back of the hand.

m. Palmar Interossei, three in number, descend on and supply the interossei muscles in the three inner metacarpal spaces.

The branches which arise from the radial may be arranged according to their distribution in six groups—

1st. To muscles of fore arm : muscular arteries.

2d. To elbow joint : radial recurrent artery.

3d. To wrist joint : anterior and posterior radial carpal and recurrent of deep arch.

4th. To muscles of thumb : superficial volar artery.

5th. To interossei muscles : dorsal and palmar interosseous arteries.

6th. To digits : *arteria magna pollicis* and *art. radialis indicis*.

Inosculations take place freely in the upper limb between the branches of the different arteries. Around the shoulder the scapulo-humeral set of branches of the axillary anastomose with each other, and with the posterior and suprascapular branches of the subclavian. In the upper arm anastomoses take place between the muscular branches of the brachial and the circumflex

branches of the axillary. Around the elbow joint the three descending branches of the brachial artery, viz., the superior profunda, inferior profunda and anastomotic, inosculate with the four ascending or recurrent arteries. Thus, at the outer and anterior part of the joint, the superior profunda anastomoses with the radial recurrent, and at the outer and posterior the superior profunda with the posterior interosseous recurrent; at the inner and anterior part the anastomotic inosculates with the anterior ulnar recurrent, and at the inner and posterior the anastomotic and inferior profunda with the posterior ulnar recurrent. If the brachial artery were tied or occluded from any cause, these anastomoses would enlarge and convey the blood into the arteries of the fore arm.

In the front of the fore arm the short muscular branches of the radial and ulnar arteries anastomose with each other, and with the anterior interosseous of the ulnar; and on the back of the fore arm, the posterior interosseous with the perforating branch of the anterior interosseous. Around the wrist joint not only are there the inosculations of the carpal arches, but the anterior carpal arch anastomoses with the anterior interosseous and the recurrent branches of the deep palmar arch; and the posterior carpal arch with the perforating branch of the anterior interosseous. In the hand the anastomoses are numerous; not only does the ulnar artery itself join the volar and index branches of the radial artery to form the superficial palmar arch; and the radial artery itself join the deep branch of the ulnar to form the deep arch; but the palmar interosseous branches of the deep arch anastomose with the digital branches of the superficial arch; again the two digital

arteries passing along the borders of each digit anastomose on the palmar surface of the ungual phalanx, and the perforating branches of the deep arch anastomose on the back of the hand with the metacarpal and posterior carpal arteries. Owing to the multiplicity and freedom of the inosculations in the hand, wounds of the arteries are apt to occasion troublesome hæmorrhage. If in the development of the arteries of the hand any one of the vessels has not reached its ordinary dimensions, in order to compensate for its reduced size, one or more of the arteries which inosculate with it is more largely developed, so as to convey to the part the amount of blood that is required for nutrition ; from this circumstance variations in the relative size of the arteries are not unfrequently found in the hand.

Carotid System of Arteries.

This system is composed of the arteries of supply for the neck and head, and consists of the common carotid artery, of its two branches of bifurcation, the internal and external carotids, and of their several branches.

The COMMON CAROTID artery varies in its origin on the two sides of the body. On the right side it arises from the arteria innominata opposite the right sterno-clavicular joint ; on the left it arises from the transverse part of the arch of the aorta between the arteria innominata and the left subclavian artery, but nearer to the former than to the latter. Both common carotids run up the neck by the sides of the windpipe, and when they reach the level of the upper border of the thyroid cartilage they divide into the internal and external carotid arteries.

The left common carotid is longer than the right ; it is placed at first in the upper part of the thorax, in which it ascends as far as the left sterno-clavicular joint ; it is covered by the manubrium sterni and the remains of the thymus gland, and is crossed by the left innominate vein. It lies at first in front of the trachea, and then in front of the œsophagus and thoracic duct.

In the neck each common carotid artery is enclosed along with the internal jugular vein and vagus nerve in a sheath, formed of the cervical fascia ; it is covered in the lower part of the neck by the sterno-thyroid, sterno-hyoid, and sterno-mastoid muscles, cervical fascia, platysma, and skin ; it is crossed opposite the cricoid cartilage by the anterior belly of the omo-hyoid muscle, above which it lies in the anterior triangular space, where it is overlapped by the inner border of the sterno-mastoid, which forms a definite guide to the position of the artery, and is covered by the cervical fascia, platysma and skin. It rests behind on the cervical vertebræ, the longus colli, and rectus anticus major muscles, and the inferior thyroid artery crosses behind its sheath. To the inner side of the artery are the trachea, larynx, thyroid body and pharynx, and the thyroid body when enlarged overlaps the artery. The greater width of the larynx than of the trachea causes the two carotids to be further asunder in the upper than the lower part of their course. A chain of lymphatic glands lies in the neck parallel to the common carotid, and when enlarged they sometimes overlap the artery. The internal jugular vein descends close to the outer side of the artery in the same sheath, whilst the superior thyroid vein, which joins the internal jugular, crosses the upper part of the artery, and

the anterior jugular vein, which joins the subclavian, crosses its lower part. The descendens noni and communicantes noni nerves lie in front of the carotid sheath; the vagus nerve is within the sheath, parallel to but behind and between the carotid artery and internal jugular vein; the cord of the sympathetic lies behind the sheath, between it and the pre-vertebral muscles; the recurrent laryngeal branch of the vagus ascends to the larynx obliquely behind the lower part of the artery.

From the common carotid artery no collateral branches arise, but in addition to the terminal internal and external carotids, it gives off at and near its bifurcation some fine twigs, which form the *intercarotic ganglion* or *intercarotic body*. This body is sometimes referred to the sympathetic nervous system, but, as Julius Arnold has shown, it is principally formed, like the coccygeal body, of tortuous and dilated arterial twigs. The walls of the dilatations are not so thick as in the coccygeal body, the muscular coat is said to be absent, but the dilatations contain layers of polygonal cells. Branched nerve cells are found in the connective tissue which envelopes the body.

The INTERNAL or DEEP CAROTID artery, one of the two terminal branches of the common carotid, begins opposite the upper border of the thyroid cartilage; it ascends in the neck at the side of the pharynx and tonsil, as high as the base of the skull, then enters the carotid canal in the petrous-temporal, leaves that canal at its upper orifice and enters the cranial cavity, where it lies in a groove on the side of the body of the sphenoid bone; here it forms a sigmoid curve, and terminates close to the anterior clinoid process by dividing into the anterior and

middle cerebral arteries. At its origin in the neck it lies in the anterior triangular space, and is covered only by the skin, platysma, and cervical fascia; but as it ascends it becomes more deeply placed, and the posterior belly of the digastric and stylo-hyoid muscles, the hypoglossal nerve, the external carotid and occipital arteries, the parotid gland, the styloglossus and stylo-pharyngeus muscles, stylo-hyoid ligament, glosso-pharyngeal nerve and pharyngeal branches of the nervus vagus are between it and the surface. It lies in front of the rectus capitis anticus major muscle and the cervical vertebræ. To its outer side is the internal jugular vein, whilst the vagus nerve and the cord of the sympathetic are behind it.

In the carotid canal and cranial cavity the artery is accompanied by the ascending prolongation of the gangliated cord of the sympathetic, which forms the carotid and cavernous plexuses around the artery. On the side of the body of the sphenoid it lies on the inner wall of the cavernous blood sinus, and has the sixth cranial nerve in contact with its outer surface; whilst the third and fourth cranial nerves, and the ophthalmic division of the fifth lie in the outer wall of the cavernous sinus. Close to the anterior clinoid process it pierces the dura mater, and becomes covered by the visceral arachnoid prior to its termination.

No branch arises from the internal carotid in the neck. In the carotid canal a small *tympanic* branch arises, which enters the tympanum. When in the inner wall of the cavernous sinus minute branches, named *arteriæ receptaculi*, pass to the walls of the sinus; but the chief branches of the internal carotid are to the eyeball and other contents of the orbit, and to the brain.

The *Ophthalmic* branch arises close to the anterior clinoid process, enters the orbit, along with the optic nerve, through the optic foramen and runs forwards and inwards above the optic nerve to end in branches to the nose and forehead. It gives origin to the following branches: *lachrymal*, which runs forwards in relation to the outer side of the roof of the orbit, and supplies the lachrymal gland, conjunctiva, and eyelids: *arteria centralis retinae*, which passes into the optic nerve, enters the eyeball along with it, and supplies the retina: *ciliary* branches, which accompany the optic nerve and pierce the sclerotic coat to ramify in the choroid coat, ciliary processes, and iris: *muscular* branches to the muscles: *anterior* and *posterior ethmoidal* branches, which pass through the ethmoidal foramina, and supply the adjacent part of the dura mater: *palpebral* branches to the two eye-lids: *nasal* branch to the root of the nose: *supra-orbital* branch, which passes through the supra-orbital notch to the skin and muscles of the forehead: and a *frontal* branch, which is distributed to the forehead, internal to the supra-orbital.

The branches of the internal carotid for the supply of the brain are the middle and anterior cerebral and the posterior communicating.

The *Middle Cerebral* artery extends outwards into the Sylvian fissure, divides into branches in the pia mater, and supplies the island of Reil, the orbital convolutions, the inferior and ascending frontal convolutions, and the convolutions of the parietal and temporo-sphenoidal lobes: it also gives *perforating* branches through the locus perforatus anticus to the corpus striatum, and sends a *choroid* branch to the choroid plexus of the velum interpositum

The *Anterior Cerebral* artery runs forward in the longitudinal fissure, then turns upwards in front of the corpus

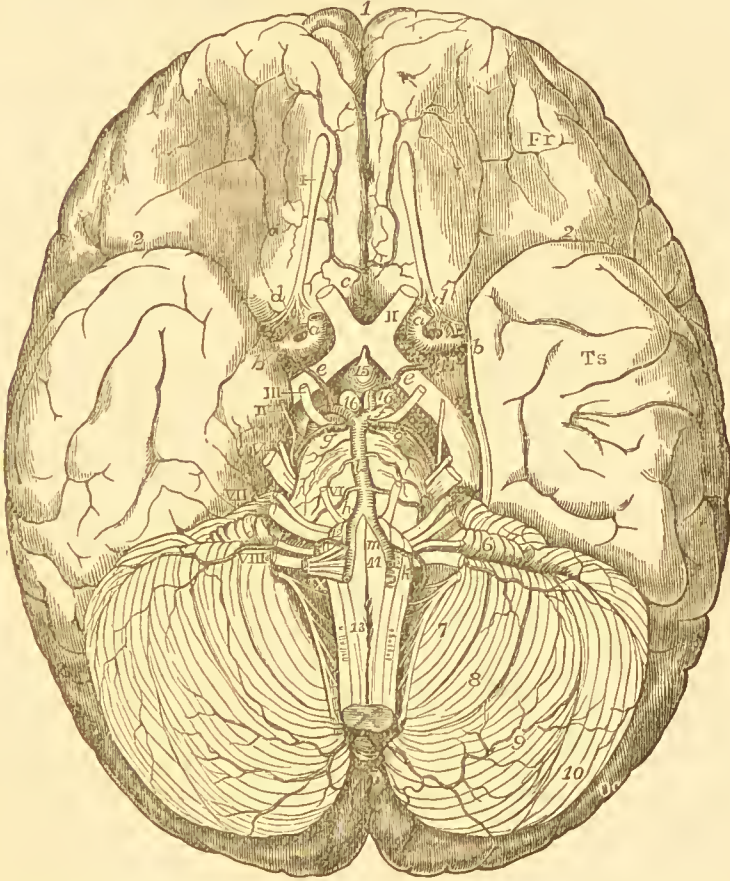


FIG. 127.—Diagram of the base of the Brain with its arteries. I. to IX. cranial nerves; *a a*, internal carotid artery; *b b*, middle cerebral; *c*, anterior communicating; *d d*, anterior cerebral; *e e*, posterior communicating; *f*, posterior cerebral; *g g*, superior cerebellar; *h* and *k*, inferior cerebellar; *l*, basilar; *m*, vertebral artery; *Fr*, frontal lobe; *Ts*, temporo-sphenoidal lobe; *Oc*, occipital lobe; 1, great longitudinal fissure; 2, Sylvian fissure; 6, flocculus; 7, tonsil, 8, postero-inferior; 9, slender; 10, biventral lobes of cerebellum; 11, left anterior pyramid; 12, right olivary body; 13, decussation of the pyramids; 14, left anterior perforated space; 15, tuber cinereum and infundibulum; 16, 16, corpora albicantia.

callosum, and then passes backwards in close relation to its upper surface: it supplies the convolutions of the inner

face of the hemisphere from the anterior end of the frontal lobe as far back as the internal parieto-occipital fissure, also the corpus callosum, and the superior and middle frontal convolutions.

The *Posterior Communicating* artery is a slender branch which runs backwards to anastomose with the posterior cerebral artery.

At the base of the brain not only do the two internal carotids anastomose with each other through the *anterior communicating* artery, which passes between their anterior cerebral branches, but the internal carotid on each side anastomoses with the posterior cerebral branch of the basilar, by a *posterior communicating* artery. In this manner a vascular circle, the *circle of Willis*, is formed, which permits of freedom of the arterial circulation by the anastomoses between arteries not only on the same side, but on opposite sides of the mesial plane.

But further, the branches which pass to the convoluted surface of the hemisphere anastomose to some extent with each other; thus the anterior and middle cerebral anastomose on the frontal lobe, and the anterior and posterior cerebral anastomose on the inner face of the hemisphere near the posterior end of the corpus callosum.

The vertebral and internal carotid arteries, which are the arteries of supply for the brain, are distinguished by lying at some depth from the surface in their course to the organ, by having curves or twists in their course, whereby the force of the flow of blood is retarded, and by the absence of large collateral branches. Further, as the ophthalmic artery is a branch of the internal carotid, the circulation in the eyeball is in sympathy with that in the brain.

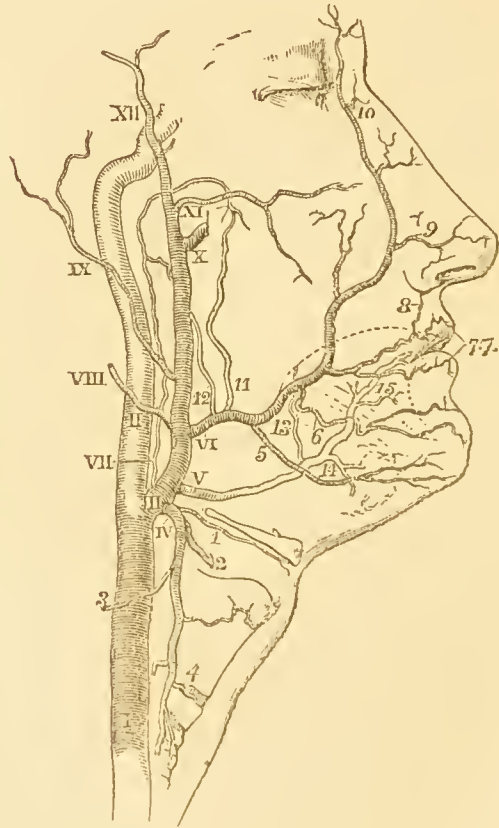
The EXTERNAL CAROTID artery is the more superficial of the two terminal branches of the common carotid : it begins opposite the upper border of the thyroid cartilage, and ascends to opposite the neck of the condyle of the lower jaw, where it divides into two terminal branches, the temporal and internal maxillary arteries. At its commencement it lies in the anterior triangular space of the neck internal to the internal carotid artery, overlapped by the sterno-mastoid, and covered by the skin, platysma, and fascia ; but as it ascends it reaches a plane superficial to that artery, and is crossed by the hypoglossal nerve and the posterior belly of the digastric and the stylohyoid muscles. It then enters the substance of the parotid gland, where it is crossed by the facial nerve and external jugular vein. In the upper part of its course it is separated from the internal carotid artery by the stylohyoid ligament, styloglossus and pharyngeus muscles, glossopharyngeal nerve, and pharyngeal branches of the nervus vagus.

The external carotid gives origin to a number of branches, of which the superior thyroid, lingual, facial, and internal maxillary run forwards and inwards ; the occipital and posterior auricular run backwards and outwards ; and the ascending pharyngeal and temporal run almost directly upwards.

a. Superior Thyroid artery arises from the external carotid close to its origin ; it runs downwards and inwards in relation to the superior cornu of the thyroid cartilage, and ends in the substance of the thyroid body. From it arise a *hyoid* branch, which runs inwards below the hyoid bone : a *sterno-mastoid* branch which runs downwards and

outwards, superficial to the carotid sheath, to supply the sterno-mastoid muscle : a *superior laryngeal* branch, which pierces the thyro-hyoid membrane, along with the superior laryngeal nerve, and supplies the mucous membrane

FIG. 128.—Diagram of the Carotid arteries. I. common carotid; II. internal, and III. external carotid; IV. superior thyroid; V. lingual; VI. facial; VII. ascending pharyngeal; VIII. occipital; IX. posterior auricular; X. internal maxillary; XI. transverse facial; XII. temporal. 1, hyoid branch of superior thyroid; 2, superior laryngeal branch; 3, sterno-mastoid branch; 4, terminal branches; 5, submental branch of facial; 6, inferior labial; 7, coronary; 8, septal branch; 9, lateral nasal; 10, angular termination of facial; 11 and 12, tonsillary and ascending palatine branches of facial.



and muscles of the larynx : a *crico-thyroid* branch, which runs inwards superficial to the crico-thyroid membrane, and forms by anastomosing with the opposite crico-thyroid artery an arterial arch. The *terminal thyroid* branches supply the lateral lobe of the thyroid body, and inosculate with the inferior thyroid of the subclavian ; a branch also

runs along the upper border of the isthmus to join the opposite superior thyroid.

b. The *Lingual* artery arises just above the superior thyroid artery, and runs upwards and inwards, above the great cornu of the hyoid bone to the under surface of the tongue. It passes between the hyo-glossus and middle constrictor muscles, and then between the mylo-hoid and genio-hyo-glossus, when it assumes the name of *ranine* artery. From it arise a *hyoid* branch, which runs inwards in relation to the upper border of the hyoid bone : a *dorsalis linguae* branch, which supplies the muscular substance and mucous membrane of the dorsum of the tongue ; this branch is usually represented by a number of small branches : a *sublingual* branch, which supplies the sublingual gland and the adjacent muscles. The *ranine* termination of the lingual artery runs along the under surface of the tongue as far as the tip to supply its muscles and mucous membrane.

c. *Facial* artery arises above the lingual, but sometimes along with it by a common trunk. It runs upwards and inwards through the digastric triangle, then mounts over the horizontal ramus of the lower jaw, close to the anterior border of the masseter muscle, and ascends in a tortuous manner across the side of the face, close to the angle of the mouth, the angle of the nose, and the inner angle of the eye. It is crossed immediately after its origin by the stylo-hyoid and posterior belly of the digastric muscles, and when in the digastric triangle it is enclosed by the submaxillary gland. On the face it is covered by the platysma and zygomatic muscles, and lies on the buccinator, levator anguli oris, and levator labii superioris. The

artery when on the face is crossed by the branches of the facial nerve, but the facial vein is not in close relation to it. From it arise an *ascending palatine* branch, which ascends between the stylo-glossus and stylo-pharyngeus muscles to supply the wall of the pharynx, tonsil, and soft palate: a *tonsillar* branch to the tonsil and side of the tongue: *glandular* branches to the sub-maxillary gland: a *sub-mental* branch, which runs below the lower jaw to the chin: *posterior facial* branches, which run backwards to the masseteric region: *inferior labial* branch, which runs forward to the skin and muscles of the lower lip: two *coronary* branches, one to run along the free margin of each lip immediately beneath the mucous membrane,—each inosculates with the corresponding artery of the opposite side, and forms an arterial arch, and from the superior coronary arch the *septal* artery ascends to the nasal septum: *lateral nasal*, a branch distributed to the side of the nose. The terminal part of the facial is the *angular* artery, which anastomoses at the inner angle of the orbit with the nasal branch of the ophthalmic artery.

d. Occipital artery arises from the posterior surface of the external carotid, and passes upwards and backwards to the occipital region. It goes under cover of the posterior belly of the digastric, and is crossed by the hypoglossal nerve; it then reaches the mastoid-temporal and occipital bones, where it is covered by the sterno-mastoid, splenius, and often by the trachelo-mastoid muscle, whilst it rests on the complexus and superior oblique. It then passes through the occipital origin of the trapezius, along with the great occipital nerve, and is distributed to the back of the scalp. From it arise a *sterno-mastoid* branch to the

sterno-mastoid muscle : a *meningeal* branch, which ascends through the jugular foramen to the dura mater : *princeps cervicis* branch to the deep muscles of the back of the neck : *occipital* branches to the scalp.

e. Posterior Auricular artery arises from the external carotid in the substance of the parotid gland. It ascends behind the ear, and supplies *auricular* branches to the back of the auricle of the ear ; *cranial* branches to the scalp adjacent to the ear : and a *stylo-mastoid* branch, which enters the stylo-mastoid foramen.

f. Ascending Pharyngeal artery arises close to the origin of the external carotid, and ascends in relation to the wall of the pharynx to supply it, the tonsil, and soft palate ; its size is in inverse ratio to that of the ascending palatine branch of the facial. It also gives *meningeal* branches through the jugular foramen to the dura mater.

g. Temporal artery, one of the two terminal branches of the external carotid, arises in the parotid gland. It ascends superficially to the root of the zygoma, and in front of the ear to the scalp, where it divides into two branches, an *anterior* and a *posterior temporal* artery, which supply the scalp of the side of the head and the anterior surface of the auricle : in old persons the temporal branches become very tortuous. The temporal artery, whilst in the parotid, gives origin to the *transverse facial* artery, which runs forwards to the face superficial to the masseter, and immediately below the zygoma : the transverse facial sometimes arises directly from the external carotid.

h. Internal Maxillary artery, the larger of the two terminal branches of the external carotid, arises in the substance of the parotid gland, and passes forwards and

inwards under cover of the ascending ramus of the lower jaw as far as the spheno-maxillary fossa, where it divides into six terminal branches. In this course it lies at first below the external pterygoid muscle, and between the jaw and the internal lateral ligament; then it crosses over the external pterygoid, between that muscle and the coronoid insertion of the temporal, though it not unfrequently pierces the external pterygoid, or even goes behind it; and lastly it dips between the two heads of the external pterygoid, and enters the spheno-maxillary fossa. Its branches are numerous, and are usually arranged in three sets.

The first set of branches arise between the jaw and the internal lateral ligament, and in their course enter foramina or fissures in the bones of the head. They are as follows:—*tympanic* branch passes through the Glaserian fissure to supply the mucous membrane of the tympanum: *middle meningeal* branch ascends under cover of the external pterygoid muscle to the foramen spinosum in the ali-sphenoid, and ramifies extensively in the dura mater to supply it and the inner table of the cranial bones; it gives off a *small meningeal* branch, which enters the skull through the foramen ovale: *inferior dental* branch, which accompanies the inferior dental nerve along the dental canal in the lower jaw, and supplies the teeth; when opposite the mental foramen it gives a *mental* branch to the structures of the chin.

The second set of branches arise from the internal maxillary as it lies in contact with the external pterygoid, and are distributed to muscles. They are as follows:—*masseteric* branch to the masseter: *pterygoid* branches to the two pterygoid muscles: *buccal* branch to the bucci-

nator: *deep temporal* branches which enter the deeper surface of the temporal muscle.

The third set of branches arise in the sphenomaxillary fossa, and enter foramina or fissures in the bones of the head. They are as follows:—*superior maxillary* branch runs downwards and forwards on the upper jaw, supplies the gum, and sends *superior dental* branches through small foramina in the upper jaw, which accompany branches of the superior dental nerve to the pulps of the upper teeth: *infra-orbital* branch enters the infra-orbital canal, and emerges on the face, along with the infra-orbital nerve, at the infra-orbital foramen; it supplies the lower eyelid and adjacent parts of the face: *descending palatine* branch runs down the posterior palatine canal along with the descending palatine nerve, and emerges at the posterior palatine foramen on the back of the hard palate to supply the palatal mucous membrane: *spheno-palatine* branch runs inwards to the nose, along with the spheno-palatine nerve, and supplies the nasal mucous membrane; one branch runs down the nasal septum, and appears on the roof of the mouth at the anterior palatine foramen: *vidian* branch passes backwards by the side of the vidian nerve through the vidian canal, and supplies the Eustachian tube and adjacent part of the pharynx: *pterygo-palatine* branch runs backwards, along with the pterygo-palatine nerve, through the pterygo-palatine canal to the roof of the pharynx.

The branches of the external carotid artery may be arranged according to their distribution in five groups:—

1st. To thyroid body and larynx: superior thyro artery.

2d. To tongue: lingual artery.

3*d.* To palate and face : facial artery.

4*th.* To scalp and auricle : occipital, posterior auricular and temporal arteries.

5*th.* To pharynx, palate, deep parts of face, teeth, nose, and membranes of brain : ascending pharyngeal and internal maxillary arteries.

Important anastomoses take place not only between the branches of the carotid arteries, but also between them and those of the subclavian. The principal anastomoses may be arranged as follows :—

1*st.* Between the external and internal carotids of the same side : *a*, temporal with supra-orbital and frontal ; *b*, angular termination of facial with nasal branch of ophthalmic.

2*d.* Between branches of external carotid of the same side : *a*, temporal with posterior auricular and occipital ; *b*, facial with transverse facial and with buccal, infra-orbital and mental branches of internal maxillary ; *c*, ascending palatine of facial with ascending pharyngeal, and with descending palatine of internal maxillary.

3*d.* Between branches of external carotids of opposite sides : *a*, facial with facial ; *b*, temporal with temporal ; *c*, occipital with occipital ; *d*, superior thyroid with superior thyroid.

4*th.* Between branches of internal carotids of opposite sides : anterior cerebral with anterior cerebral, through the anterior communicating.

5*th.* Between the subclavian and external carotid of the same side : *a*, deep cervical with princeps cervicis of occipital ; *b*, vertebral with occipital ; *c*, inferior thyroid with superior thyroid.

6th. Between the subclavian and internal carotid of the same side: vertebral through the basilar and posterior cerebral with the posterior communicating of the internal carotid.

7th. Between branches of subclavians of opposite sides. The two vertebals with each other to form the basilar artery.

The anastomoses of the branches of the external and internal carotid with those of the subclavian enlarge, and form secondary channels for the conveyance of blood to the face, head, and the upper part of the neck when the common carotid artery is obstructed by the application of a ligature.

FOURTH GROUP—BRANCHES OF THE AORTA FOR THE LOWER LIMBS AND PELVIS.

This group consists of the iliac system of arteries, which are produced by the so-called bifurcation of the abdominal aorta.

Iliac System of Arteries.

This system is composed of the arteries of supply for the pelvis and lower limb, and consists of the common iliac, the external and internal iliac arteries and their several branches.

The COMMON ILIAC artery springs from the abdominal aorta, at its so-called bifurcation, opposite the body of the fourth lumbar vertebra. It passes downwards and outwards for about two inches, and bifurcates opposite the side of the lumbo-sacral joint into the external and internal

iliac arteries. Each common iliac lies behind the peritoneum covering the posterior wall of the abdomen, and is overlapped by the small intestine. Each is crossed by the ureter and the branches of the sympathetic cord to the hypogastric plexus, and the left in addition by the inferior mesenteric vessels. Each is in front of the bodies of the two lower lumbar vertebræ, but the two common iliac veins are interposed between the right artery and the last lumbar vertebra, whilst the left common iliac vein lies below its corresponding artery. No collateral branches arise from the common iliac.

The EXTERNAL ILIAC artery is the commencement of the great arterial trunk for the lower limb; it is the larger of the two branches of bifurcation of the common iliac, and passes downwards and outwards within the cavity of the abdomen as far as Poupart's ligament, where it becomes the femoral artery. It lies behind the peritoneum covering the posterior wall of the abdomen, and is overlapped by the intestines. It rests on the fascia covering the inner border of the psoas muscle close to the pelvic inlet. The external iliac vein lies behind the upper end of the artery, but on the same plane and internal to its lower end, where it receives the deep circumflex iliac vein, which crosses in front of the artery. The genito-crural nerve is at first external and then anterior to it; lymphatic glands and vessels run close to its anterior and inner aspects. Its only branches are distributed to the muscles of the abdominal wall, and are as follows:—

a. *Deep Epigastric* artery arises just above Poupart's ligament and ascends, immediately to the inner side of the internal or deep abdominal ring, to the anterior wall of the

abdomen between the fascia transversalis and the peritoneum ; it then enters the sheath of the rectus abdominis, and, continuing to ascend, supplies that muscle and inosculates with the superior epigastric branch of the internal mammary artery. As it lies to the inner side of the internal or deep abdominal ring, the vas deferens, which passes through the ring in its course to the pelvis, turns behind the artery. It gives off *transverse* branches, which pass outwards to inosculate with the lower aortic intercostal, lumbar, and deep circumflex iliac arteries : a *cremasteric* branch to the coverings of the spermatic cord ; a *pubic* branch runs inwards to the back of the pubes, inosculates with the obturator artery, and sometimes enlarges so as to form the origin of the obturator artery.

b. *Deep Circumflex Iliac* artery arises from the external iliac close to Poupart's ligament : it runs outwards behind that ligament to the iliac crest, supplies the muscles attached to the crest, also the iliacus, and inosculates with the lumbar, ilio-lumbar, and deep epigastric arteries.

The FEMORAL artery is the direct continuation of the external iliac : it commences at Poupart's ligament, runs down the anterior and inner aspects of the thigh, as far as the opening in the tendon of the adductor magnus muscle, where it becomes the popliteal artery. In this course the artery passes at first through the triangular space of Scarpa, from the middle of its base to its apex, and is covered by the skin, superficial fascia, and fascia lata, but at the base of the triangle it has an additional investment from the femoral sheath. Near the apex of Scarpa's triangle the artery goes under cover of the sartorius muscle, behind which it descends to its termination. For about three

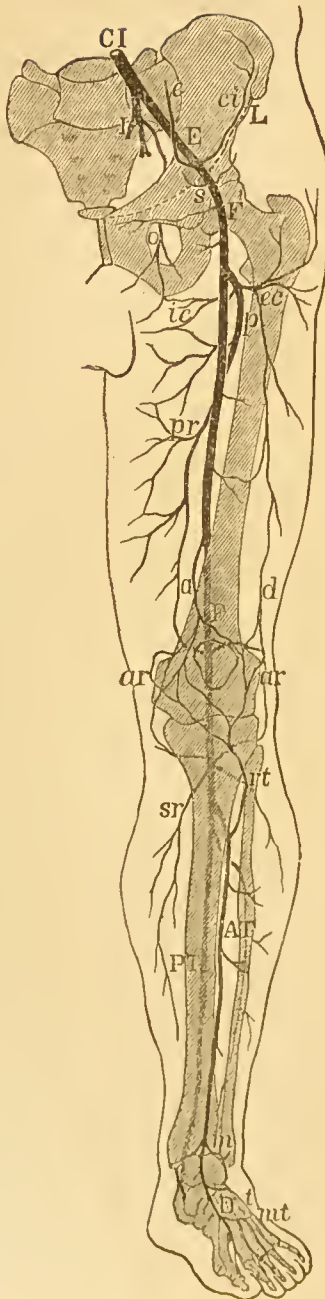


FIG. 129.—The Arteries of the Lower Limb. CI, common iliac; I, internal iliac, and E, external iliac artery; F, femoral artery; P, popliteal; PT, posterior tibial; AT, anterior tibial artery; D, dorsal artery of foot; e, deep epigastric, and cl, deep circumflex iliac arteries; o, obturator artery; s, superficial branches of femoral; p, profunda artery; ec, external circumflex; ic, internal circumflex, and pr, perforating series of branches; a, anastomotic artery; d, descending branch of external circumflex; ar ar, articular arteries; rt, recurrent tibial branch; sr, sural branch; m, malleolar arteries; t, tarsal, and mt, metatarsal branches; L, Poupart's ligament.

inches above the opening in the tendon of the adductor magnus it lies in Hunter's canal—a canal bounded externally by the tendon of the vastus internus, posteriorly by the tendons of the adductor longus and magnus, and anteriorly by a fibrous prolongation from the tendon of the vastus to those of the two adductors. When in this canal the artery is in close relation to the inner surface of the middle third of the femur. Close to the apex of Scarpa's triangle it is in relation to the inner border of the sartorius muscle, which forms a definite guide to the position of the artery. Behind the artery is the psoas muscle, by which it is separated from the capsule of the hip joint and the head of the thigh bone; lower down the artery is in front of the pectineus, but separated from it by the deep femoral vessels, and still lower the artery has the tendons of the adductor longus and magnus posterior to it. The femoral vein is at first on the same plane and internal to the artery, and is enclosed along with it and the femoral lymphatics in the femoral sheath; about the apex of Scarpa's triangle the vein sinks behind the artery, and remains posterior to it as far as the popliteal space. The long saphenous vein is superficial, and to the inner side of the artery, and separated from it by the fascia lata. The anterior crural nerve is to the outer side of the artery near the base of Scarpa's triangle; of its several branches the internal cutaneous nerve crosses the artery near the apex of the triangle: the internal saphenous accompanies the artery into Hunter's canal, but when the artery leaves the canal to enter the popliteal space, the nerve perforates its fibrous wall, and becomes cutaneous near the inner side of the knee joint. The branches of the femoral artery are as follows:—

As the artery lies in the femoral sheath, it gives origin to three superficial branches, which pierce the fascia lata, and end in the skin, superficial fascia, and lymphatic glands of the groin.

a. Superficial Circumflex Iliac, which runs outwards to the anterior superior iliac spine.

b. Superficial Epigastric, which ascends in front of Poupart's ligament to the wall of the abdomen.

c. Superficial Pudic usually consists of two branches—a superior and an inferior, which run inwards and end in the skin of the external organs of generation.

d. Muscular branches small in size, which run outwards into the muscles of the thigh.

e. Anastomotic arises near the lower end of Hunter's canal; it divides into three branches: a *cutaneous*, which runs along with the long saphenous nerve behind the sartorius to the inner side of the knee: a *muscular*, which passes into the substance of the vastus internus, and is distributed as low down as the knee: an *articular*, which descends directly to the knee on the tendon of the adductor magnus inserted into the internal femoral condyle.

The largest and most important branch of the femoral is

f. The Profunda, or Deep Femoral artery, which arises in Scarpa's triangle from the posterior and outer part of the femoral from one and a half to two inches below Poupart's ligament. It descends behind the femoral artery and the tendon of the adductor longus, and pierces the substance of the adductor magnus muscle. It has the iliacus, pectineus, adductor brevis and adductor magnus muscles behind it, and the femoral and profunda veins lie between it and the femoral artery. From it arise the following

branches : *external circumflex*, which passes outwards behind the rectus and sartorius and between the branches of the anterior crural nerve to divide into ascending, transverse and descending branches ; the *ascending* passes under the tensor fasciæ femoris to anastomose with the gluteal artery ; the *transverse* enters the substance of the vastus externus, and the *descending* passes downwards and outwards on and in the vastus externus, partly to supply that muscle, and partly to reach the outer side of the knee. Sometimes the external circumflex arises directly from the femoral, and sometimes its ascending, or its ascending and transverse branches arise from the femoral, whilst the descending branch springs as an independent branch from the profunda. The *internal circumflex* arises from the inner side of the profunda opposite the origin of the external circumflex : it runs backwards first between the psoas and pectineus, then between the adductor brevis and obturator externus, then between the adductor magnus and quadratus femoris to reach the back of the thigh ; it supplies the muscles between which it passes, also the hip joint. The *perforating* branches, usually three in number, and named, from above downwards, *first*, *second*, and *third perforating*, pass to the back of the thigh to supply the hamstrings ; the first and second pierce the short and great adductors. The second perforating gives origin to the small *nutrient* artery which enters the nutrient canal in the femur to supply the medulla of the bone. The *terminal* part of the profunda, sometimes called the *fourth perforating* artery, not only supplies the adductor magnus, but gives branches to the short head of the biceps.

The branches which arise either directly or indirectly

from the femoral artery may be arranged according to their distribution as follows :—

1st. To glands, fat, and skin of groin : superficial pudic, epigastric and circumflex iliac arteries.

2d. To muscles : muscular branches, profunda artery.

3d. To bone : nutrient artery.

4th. To hip joint : external and internal circumflex arteries.

5th. To knee joint : anastomotic and descending branch of external circumflex artery.

The profunda artery with its branches is the great muscular artery of the thigh. Occasionally in the upper limb an arrangement similar to the profunda in the thigh occurs, when the circumflex, subscapular, superior and inferior profunda arteries arise by a common trunk from the axillary artery.

By some descriptive writers the part of the femoral prior to the origin of the profunda is called common femoral ; which is then said to divide into a superficial femoral and a deep femoral artery, the deep femoral being looked upon therefore as a terminal branch of bifurcation, and not as a large collateral branch.

The POPLITEAL artery is the direct continuation of the femoral artery ; it commences at the opening in the adductor magnus, passes down the popliteal space, or ham, as far as its inferior angle, and reaches the lower border of the popliteus muscle, where it divides into two terminal branches, the anterior and posterior tibial arteries. It lies immediately behind the back of the lower end of the femur, the posterior ligament of the knee joint, and the popliteus muscle, so that it is in close relation to the floor of the popliteal space, and is separated from the surface of

the back of the limb by a considerable interval. To its outer side in the upper half of the space is the biceps, and in the lower half the outer head of the gastrocnemius and the plantaris. It enters the space by passing in front of the semi-membranosus, and then has that muscle with the semi-tendinosus to its inner side in the upper half of the space, and the inner head of the gastrocnemius in its lower half : as the two heads of the gastrocnemius approach each other at the lower angle of the space they overlap the artery. The popliteal vein lies immediately posterior to the artery, at its upper part being a little to its outer side, at its lower part a little to its inner side. The internal popliteal nerve is also posterior to the artery, but nearer to the surface of the region ; like the vein it is at first somewhat external, but in the lower part of the region it lies to the inner side of the artery.

The branches of the popliteal artery are distributed to the knee joint, to the muscles around it, and to the skin of the popliteal space.

a. Superior Muscular pass to the lower end of the hamstring muscles.

b. Inferior Muscular or *Sural*, to the heads of the gastrocnemius and to the plantaris.

c. Superior Internal Articular turns round the femur above the inner condyle, and under cover of the adductor magnus tendon and the inner hamstrings, to reach the inner side of the knee.

d. Superior External Articular turns round the femur immediately above the outer condyle, and under cover of the biceps to reach the outer side of the knee.

e. Inferior Internal Articular runs inwards below the

internal tuberosity of the tibia and under cover of the internal lateral ligament to the inner side of the knee.

f. Inferior External Articular runs outwards under the outer head of the gastrocnemius and the external lateral ligament, and above the head of the fibula to the outer side of the knee.

g. Azygos Articular pierces the posterior ligament of the knee, and is distributed to the crucial ligaments and synovial membrane.

h. Cutaneous branch or branches arise either from the popliteal or from its muscular arteries to supply the skin of the popliteal space and calf of the leg.

The ANTERIOR TIBIAL artery is the smaller of the two terminal branches of the popliteal. It passes at first directly forwards between the tibia and fibula, then descends on the front of the leg as far as the front of the ankle, where it becomes the dorsal artery of the foot. As it passes forwards it lies above the upper end of the tibialis posticus and the interosseous membrane. On the front of the leg it rests on the front of the interosseous membrane for about its upper two-thirds, but for the rest of its course on the front of the tibia. In the upper part of the leg it is deeply placed between the muscles, with the tibialis anticus on its inner side, and the extensor communis digitorum and extensor longus hallucis on its outer side. Above the ankle, where it rests on the tibia, it is covered by the anterior annular ligament of the fascia of the leg, and is crossed by the tendon of the extensor longus hallucis. It is accompanied by the two venæ comites, and the anterior tibial nerve lies in close relation to it. Its branches are as follows:—

a. Muscular to the muscles of the front of the leg.

b. Recurrent Tibial Articular arises as soon as the anterior tibial has passed to the front of the leg, and ascends in the substance of the tibialis anticus to the knee.

c. External Malleolar runs outwards to the region of the external malleolus, behind the long extensor of the toes.

d. Internal Malleolar runs inwards to the region of the internal malleolus behind the tibialis anticus. The malleolar arteries supply the ankle joint.

THE DORSAL ARTERY OF THE FOOT is a direct continuation of the anterior tibial artery; it runs forwards from the front of the ankle to the first metatarsal space, where it enters the sole of the foot to join the external plantar artery and assist in the formation of the plantar arch. It rests on the inner row of tarsal bones and lies between the extensor longus hallucis and the extensor communis digitorum; it is crossed by the innermost tendon of the extensor brevis digitorum, and is covered by the skin and fascia of the dorsum of the foot. It is accompanied by two venæ comites, and the anterior tibial nerve is immediately to its outer side. Its branches are as follows:—

a. Tarsal branch runs outwards under cover of the extensor brevis digitorum to supply it and the tarsal joints.

b. Metatarsal branch arises in front of the tarsal, and passes outwards under cover of the extensor brevis. It supplies the tarso-metatarsal joints, and gives off *interosseous* branches to the three outer interosseous spaces to supply the dorsal interossei muscles, which branches are prolonged on the dorsum of the toes.

c. Marginal branches to the skin of the inner border of the foot.

d. Dorsalis Hallucis arises as the artery dips into the first metatarsal space, and runs along the dorsal surface of the great toe.

e. First Digital branch arises in the sole and runs along the inner border of the plantar surface of the great toe.

f. Second Digital branch also arises in the sole, and dividing into two, supplies the adjacent sides of the great and second toes.

The POSTERIOR TIBIAL artery is the larger of the two terminal branches of the popliteal, and continues the course of that artery down the back of the leg as far as the inner ankle, where it divides into its two terminal branches, the internal and external plantar arteries. In the upper two-thirds of its course, it is placed deeply in the limb under cover of the great muscles of the calf, but in the lower third it lies to the inner side of the tendo Achillis, and is covered by the skin and fasciæ; immediately prior to its termination, however, it passes under cover of the origin of the abductor hallucis. It rests from above downwards on the tibialis posticus, flexor longus digitorum, the tibia, and ankle joint; at the inner ankle it has the tendons of the tibialis posticus and flexor longus digitorum between it and the inner malleolus, and the tendon of the flexor longus hallucis to its outer or calcaneal side. It is accompanied by two venæ comites. The posterior tibial nerve is at first to its inner side, and then crosses behind to descend on the outer side of the artery. Its branches are as follows :—

a. Muscular branches to muscles of back of leg.

b. Nutrient branch to shaft of tibia.

c. Calcaneal branch to skin of heel.

d. Peroneal, a large branch, which descends under cover of the soleus and flexor longus hallucis, and in close relation to the fibula as far as the lower end of the leg when it passes to the outer ankle, where it terminates. It supplies *muscular* branches to the muscles of the back and outer side of the leg: a *nutrient* branch to the fibula: an *anterior peroneal* or *perforating* branch pierces the interosseous membrane, and descends to the outer side of the front of the ankle: a *communicating* branch runs transversely behind the lower end of the tibia, and joins the posterior tibial artery. It is not uncommon to find the peroneal artery much larger than the posterior tibial is below the origin of the peroneal, in which case the communicating branch is also enlarged, and through it the blood flows into the lower end of the tibial and the plantar arteries.

The INTERNAL PLANTAR artery is the smaller of the two terminal branches of the posterior tibial artery. It passes forwards close to the inner border of the sole of the foot as far as the root of the great toe, and is accompanied by the internal plantar nerve; it is covered by the abductor hallucis muscle. It supplies *marginal* branches to the skin of the inner border of the foot, and *muscular* branches to the abductor hallucis and flexor brevis digitorum.

The EXTERNAL PLANTAR artery, the larger of the two terminal branches of the posterior tibial, inclines forwards and outwards from the inner ankle as far as the base of the fifth metacarpal bone, and is accompanied by the external plantar nerve; it then runs inwards and forwards through the deepest part of the sole as far as the first metatarsal space, where it joins the dorsal artery of the foot, and forms

the PLANTAR ARTERIAL ARCH. The artery is at first covered by the skin, plantar fascia, and abductor hallucis, and rests on the os calcis, it then passes between the flexor brevis digitorum and musculus accessorius, and when it runs forwards

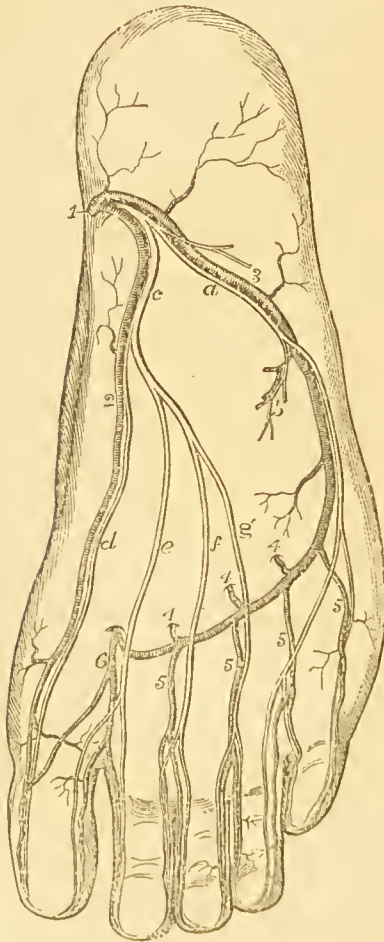


FIG. 130.—Outline Diagram of the Plantar arteries and nerves. 1, Posterior tibial artery; 2, internal plantar; 3, external plantar; 4, 4, posterior perforating branches; 5, 5, 5, 5, digital branches; 6, dorsal artery of foot appearing in the sole; a, external plantar nerve; b, its deep branch; c, internal plantar nerve; d, e, f, g, its digital branches.

and inwards in the deep part of the sole, it is covered by the flexor tendons, the lumbricales and the adductor hallucis, and it rests on the metatarsal bones and the interossei,

muscles. It supplies a *cutaneous* branch to the skin of the heel : *muscular* branches to the muscles of the sole : *marginal* branches to the skin of the outer border of the foot. From the plantar arch arise three *posterior perforating* branches, which pass between the heads of the dorsal interossei muscles and inosculate with the interosseous branches of the metatarsal artery : four *digital* branches, of which the *first* supplies the outer side of the little toe ; whilst the *second*, *third*, and *fourth* divide at the clefts between the toes, and supply the contiguous borders of the fifth and fourth, fourth and third, third and second toes ; from the digital arteries *anterior perforating* branches pass at the clefts between the toes to the dorsum of the foot, to inosculate with the branches of the metatarsal artery prolonged on to the dorsum of the toes.

The INTERNAL ILIAC artery, the smaller of the two terminal branches of the common iliac, commences at the lumbo-sacral joint, sinks into the cavity of the pelvis, and after a course of about one inch and a half, divides opposite the great sacro-sciatic foramen into several branches. It lies behind the peritoneum, and is crossed by the ureter. It is in front of the psoas, the upper origin of the pyriformis, the internal iliac vein and the lumbo-sacral nerve, and at its termination is situated in the loose areolar tissue which separates the peritoneum from the pelvic fascia.

In the foetus the internal iliac artery is a more important vessel than it is after the birth of the child, for by it the impure blood of the foetus is conveyed to the placenta. Accordingly it does not end in the pelvis, but runs along the side of the upper part of the bladder, and the back of the anterior wall of the abdomen as far as the

ternal pudic. 4th, to muscles of buttock : gluteal and sciatic. 5th, to hip-joint and external obturator muscle : obturator

a. Superior Vesical artery arises from the beginning of the hypogastric portion of the internal iliac artery, which has not altogether become obliterated ; it passes to the upper part of the bladder, which it supplies ; it gives a branch to the vas deferens.

b. Inferior Vesical artery runs to the lower part of the bladder, supplies it and the vesiculæ seminales ; one branch, also passes to the side of the prostate gland. From its distribution to the prostate, this branch is sometimes called the *vesico-prostatic* artery.

c. Middle Hæmorrhoidal artery supplies a portion of the rectum in relation to the base of the bladder. It is often a branch of the inferior vesical artery.

In the female, from the absence of the vesiculæ seminales and prostate, the corresponding branches are absent ; but in their stead are two arteries not present in the male, viz., a *Uterine* branch, which reaches the neck of the uterus, and ascends between the two layers of the broad ligament, to supply the uterus ; also, a *Vaginal* branch, which is distributed to the walls of the vagina, the bladder, and rectum.

d. Lateral Sacral artery usually consists of two branches which pass to the front of the sacrum, supply the pyriformis muscle, and send twigs into the sacral canal through the anterior sacral foramina.

e. Ilio-lumbar artery passes outwards behind the psoas into the iliac fossa, where it divides into a *lumbar* branch, which ascends to supply the muscles of the loins, and an *iliac* branch, which supplies the iliacus and gives a *nutrient*

branch to the ilium through the nutrient foramen in its ventral surface.

f. Internal or Deep Pudic artery pierces the pelvic fascia, passes out of the pelvis through the great sacro-sciatic foramen, and appears in the buttock below the pyriformis muscle, where it lies on the spine of the ischium. It then goes through the small sacro-sciatic foramen, runs forwards along the outer wall of the ischio-rectal fossa, in close relation to the inner surface of the obturator internus muscle, and ensheathed by the obturator or parietal layer of the pelvic fascia; it continues its course forwards behind the triangular ligament of the urethra, and in close relation to the side of the pubic arch, then pierces the triangular ligament, and terminates by dividing into the dorsal artery of the penis and the artery for the corpus cavernosum. It is accompanied by the deep pudic vein, and the pudic nerve. Its branches are as follows: *inferior hæmorrhoidal* arises in the outer wall of the ischio-rectal fossa, passes through the fat in that fossa, and is distributed to the lower end of the rectum, the sphincter ani, and the skin around the anus: *superficial perineal* arises in the outer wall of the ischio-rectal fossa, and runs forwards to supply the fascia and skin of the scrotum: *transverse perineal*, a small branch to the structures between the anus and the bulb of the urethra: *artery of the bulb*, a short but important artery which arises behind the triangular ligament of the urethra, passes transversely or obliquely inwards, then pierces the ligament to enter the back of the bulb; sometimes the artery of the bulb arises nearer the ischio-rectal fossa, and runs very obliquely forwards in order to reach the bulb; were the lateral operation of

lithotomy to be performed in such a case the artery would in all probability be cut through: *artery* of the *corpus cavernosum* enters the crus penis, and is distributed in the erectile structure of the corpus cavernosum penis: *dorsal artery* of the penis pierces the suspensory ligament of the penis, runs forward in the subcutaneous fascia on the dorsum of the organ, sends branches into the corpus cavernosum, and ends in the glans penis and prepuce.

In the female the internal pudic artery is much smaller than in the male, owing to the small size of the clitoris as compared with the penis. It gives off a similar set of branches, but the *superficial perineal* is distributed to the labium, the *artery to the bulb* supplies the bulbus vestibuli, and the *terminal* branches supply, the one the crus and corpus cavernosum of the clitoris, the other the dorsum and glans of the clitoris.

g. Gluteal artery, the largest branch of the internal iliac, pierces the pelvic fascia, and passes out of the pelvis through the great sacro-sciatic foramen in close relation to its upper or iliac boundary, and appears in the buttock immediately above the pyriformis muscle, where it divides into a superficial and a deep branch. The *superficial* branch runs between the gluteus medius and maximus, and enters the maximus to supply the upper portion of that muscle. The *deep* branch divides into two parts, one curves outwards along the border of attachment of the the gluteus minimus to the superior curved line, the other runs straight between the gluteus medius and minimus muscles, along with the superior gluteal nerve; both divisions of the deep branch reach the tensor fasciæ femoris

muscle, and supply it and the gluteus medius and minimus.

h. Sciatic artery pierces the pelvic fascia, and passes out of the pelvis through the great sacro-sciatic foramen, and appears in the buttock, immediately below the pyramiformis muscle, along with the great and small sciatic nerves. It gives off a *coccygeal* branch, which pierces the great sciatic ligament, supplies the origin of the gluteus maximus muscle from that ligament, and ends in the skin about the coccyx : a *comes nervi ischiatici*, a small branch, which accompanies the great sciatic nerve ; *terminal* branches, which for the most part end in the lower half of the gluteus maximus, though some supply the rotator muscles in the buttock. Not unfrequently the sciatic and pudic arteries arise from the internal iliac by a common trunk, which divides as it enters the buttock into the two arteries.

i. Obturator artery passes forwards between the peritoneum and pelvic fascia, along the side wall of the pelvis as far as the upper part of the obturator foramen, through which it passes into the thigh, where it divides into its terminal branches. It gives off in the pelvis a *pubi* branch, which anastomoses with the pubic branch of the deep epigastric artery. The *terminal* branches pass to the obturator externus, gracilis, and adductor muscles, and a branch enters the hip joint through the cotyloid notch. The obturator artery varies in its origin. In 361 cases examined by R. Quain, it arose in two-thirds from the internal iliac : in one case out of three-and-a-half from the deep epigastric ; in a very small proportion, partly from the internal iliac, and partly from the epigastric, and in an

equally small proportion from the external iliac artery. Its origin from the epigastric is due to a great increase in the size of the pubic branch of that artery. When the obturator arises from the epigastric it enters the pelvis behind its pubic wall, and in its course passes usually to the outer side of, more seldom to the front and inner side of the crural ring; a point to be kept in mind in connection with the anatomy of the parts concerned in femoral hernia.

Important anastomoses take place not only between branches belonging to the iliac system of arteries, but between some of these branches and those of other arteries.

In the wall of the abdomen, as already described, the deep epigastric and circumflex iliac of the external iliac, and the ilio-lumbar of the internal iliac, anastomose with the internal mammary of the subclavian, and with the lower intercostal and lumbar branches of the aorta. At the sacral wall of the pelvis, the lateral sacral of the internal iliac anastomoses with the middle sacral of the aorta, and with the superior hæmorrhoidal termination of the inferior mesenteric artery. At the anterior wall of the pelvis behind the os pubis, the pubic branch of the deep epigastric anastomoses with the pubic branch of the obturator.

In the lower limb the following inosculations take place around the hip joint: in the buttock and region of the trochanter major the gluteal and sciatic branches of the internal iliac with the external and internal circumflex branches of the profunda; in the region of the trochanter minor the obturator of the internal iliac with the internal circumflex of the profunda. These inosculations enlarge and form

secondary channels for conveying the blood to the lower limb when the external iliac artery is tied. In the substance of the thigh, more especially in the hamstring and adductor magnus muscles, the several perforating branches of the profunda anastomose with each other, with the circumflex branches of the profunda, with the comes nervi ischiatici branch of the sciatic, and with the superior muscular branches of the popliteal. These anastomoses enlarge and form secondary channels when the femoral artery is tied. Around the knee joint the five articular branches of the popliteal anastomose with each other, with the anastomotic branch of the femoral, with the descending branch of the external circumflex, and with the recurrent articular branch of the anterior tibial. In the front of the leg the muscular branches of the anterior tibial anastomose with each other. In the back of the leg the muscular branches of the posterior tibial and peroneal inosculate with each other, and the communicating branch of the peroneal with the posterior tibial. Around the ankle joint the internal and external malleolar branches of the anterior tibial inosculate with the anterior perforating and terminal branches of the peroneal, and with the tarsal branch of the dorsal artery of the foot. In the foot itself the dorsal artery inosculates with the external plantar artery to form the plantar arterial arch; its tarsal and metatarsal branches inosculate not only with each other, but at the outer border of the foot with the marginal branches of the external plantar, and at the inner border of the foot with the marginal branches of the internal plantar artery. The perforating branches of the plantar arch inosculate with the interosseous and digital branches of the metatarsal arte-

ries, and the collateral arteries to each toe anastomose with each other on the plantar aspect of the terminal phalanx.

Structure of the Arteries.

As a general rule, each artery is surrounded by a *sheath*, formed of connective tissue, which is attached to the outer wall of the artery by slender fibres, and the attachment is so loose, that when the artery is cut across it retracts within its sheath. The wall of the artery consists of several coats, which are distinguished from each other not only by differences in the direction of the fibres of which they are composed, but by structural differences. Some

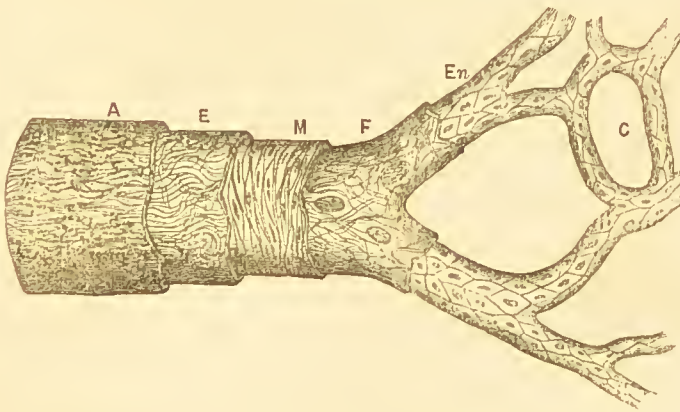


FIG. 132—Diagram of the Structure of an Artery. A, tunica adventitia; E, elastic layer; M, muscular coat; F, fenestrated layer; En, endothelium continuous with the endothelial wall of C, the capillaries.

anatomists name these coats outer, middle, and inner, but others apply to them the names of fibrous coat, elastic coat, muscular coat, fenestrated coat, and endothelial coat, a nomenclature based on their structural characters.

The *outer* coat of the artery, or *tunica adventitia*, consists of interlaced bundles of white fibrous tissue mingled with elastic fibres. In the larger arteries, the proportion of elastic tissue increases in the deeper part of this coat, so as to form an *elastic layer*. In some arteries, as the aorta, splenic, and renal arteries, bundles of non-stripped muscular fibre arranged longitudinally or obliquely, have been described in the deeper part of the outer coat.

The *middle* coat consists in medium-sized arteries chiefly of non-stripped muscular fibres, arranged transversely to the long axis of the artery, so that this coat is sometimes named the *circular* or *muscular* coat. The muscular coat forms several layers, which may be peeled asunder. Between the layers, as well as between the muscular fibres in each layer, elastic fibres are found. In the largest arteries, as the aorta and pulmonary, the proportion of the elastic to the muscular constituent of this coat is so very greatly increased as to form layers of elastic tissue in the middle coat. The elastic fibres of the middle coat pass on the one hand into the elastic layer of the outer coat, and on the other into the elastic layer of the inner coat.

The *inner coat* or *tunica intima* has its free surface, *i.e.*, the surface next the lumen of the artery, formed of a single layer of flattened, elongated, squamous endothelial cells, which give a smooth glistening surface for the blood to flow over. Outside the endothelium is an extra-endothelial layer, consisting of a delicate connective tissue in which stellate corpuscles are situated : outside this layer is the elastic or fenestrated layer, which forms the chief thickness of the inner coat. The *fenestrated* layer consists of an elastic membrane, which may be slit up into several strata.

It contains a network of elastic fibres, with spaces or perforations in it, which give it a fenestrated appearance. The inner coat may be peeled off the middle coat as a brittle film, which curls upon itself when detached from the artery. The inner coat is always cut through by the surgeon when he ties a ligature around an artery, and the middle coat is usually divided along with it; the toughness of the external coat, however, enables it to resist the application of the ligature.

The wall of an artery is nourished not by the blood which flows along the tube, but by small arteries distri-

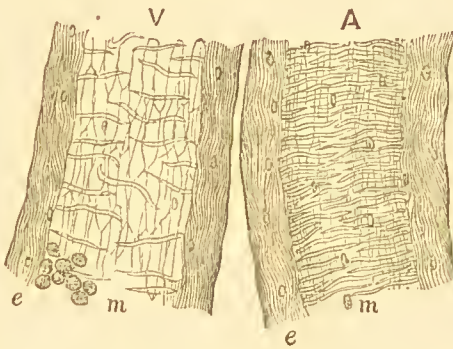


FIG. 133.—Structure of a Minute Artery A and Vein V. *e* External coat or adventitia; *m*, transversely arranged muscular tissue of the middle coat. In the vein the endothelial lining may be seen through the thin middle coat. $\times 300$ diam.

buted in its coats, which arise either from the artery itself, or from adjacent arteries. They form a network on the surface of the artery before entering its wall, and they ramify in the external and middle coat; but it is doubtful if any vessels pass into the inner coat. They end in capillaries from which veins arise. The vessels of the

wall of an artery are named *vasa vasorum*. Lymph-vessels are said to be situated in the outer coat. Nerves, chiefly derived from the sympathetic, are distributed to the muscular coat ; they form the peripheral distribution of the vaso-motor nerves.

The smallest arteries, or *arterioles*, are of microscopic size. They possess an endothelial lining, a muscular middle coat, and an external adventitia ; but the elastic fenestrated coat is absent (fig. 133). The muscular coat is reduced to a single layer of circularly arranged fibre-cells ; but in the frog, as Lister has shown, these fibre-cells are spirally arranged around the wall of the artery.

The elasticity of the wall of an artery is one of its most important physical characters, as it permits the artery to become distended under the pressure caused by the propulsion of the blood into the arteries during the ventricular contraction. When the ventricle ceases to contract the elastic wall recoils on the blood, and causes a continuous stream through the capillaries. Pulsation, or the pulse, is produced by the regular periodic modifications in the calibre of an artery. Owing to the muscularity of the arterial wall, the lumen of the tube can be lessened by the contraction of the circular muscular coat, and the amount of blood supplied to a part can be diminished. When cut across the divided end of an artery is open or gapes.

THE BLOOD CAPILLARIES.

The blood capillaries are the minute tubes which connect together the terminal branches of the arteries and the rootlets of the veins. They vary in diameter from $\frac{1}{1500}$ to $\frac{1}{3500}$ inch, and the finest capillaries are so narrow that only a single blood corpuscle can lie in the transverse diameter of the tube. The structure of the wall of a capillary blood vessel is very simple. It consists of a single layer of elongated, squamous endothelial cells, united together by their somewhat crenulated margins, so as to form the wall

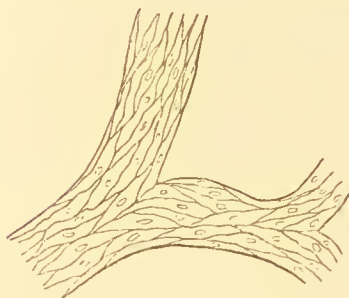


FIG. 134.—The endothelial wall of the capillaries of the retina. The outlines of the cells are stained with nitrate of silver. $\times 300$ diam.

of the tube. The outlines of these cells can be demonstrated after the addition of a solution of nitrate of silver. The nuclei of the cells are coloured by carmine, or can be seen after the addition of acetic acid. Minute spots are sometimes seen between the cells, which have been interpreted as

orifices or *stomata* in the capillary wall, but the accuracy of this interpretation is very doubtful. The endothelial wall of the capillaries is continuous with the endothelial lining of the arterics and veins, so that a continuity of the walls of the blood tubes is ensured. In many localities, as the lymph-glands and follicles, the spinal cord, the ovaries, &c., the endothelial wall is invested by a delicate coat of connective tissue, which forms a *tunica adven-*

titia for the capillary. This coat is continuous with the connective tissue of the organ in which the capillaries are situated, and also with the adventitia of the small arteries and veins which the capillaries connect together. Capillaries have no muscular coat, and the appearance of muscular fibre cells in the vascular wall indicates the passage from a simple capillary either into a minute artery or a minute vein. The endothelial wall is therefore the simple fundamental form of the blood tube, and the fenestrated, the

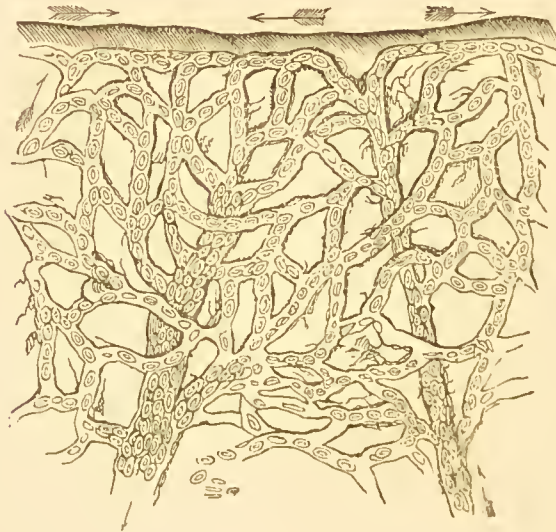


FIG. 135.—Capillary Network in the Web of the Foot of the Frog (from Allen Thomson).

muscular and the external coats are layers superadded as the blood tube increases in structural complexity.

Capillaries have a network like or plexiform arrangement in the organs of the body, but the form of the network varies in different localities, and is to some extent regulated by the

arrangement of the tissues of the organ itself. In muscles, for instance, the strands of the capillary network are elongated, parallel to and between the muscular fibres and fasciculi: in most glands the network is irregularly polygonal: around the lobules of adipose tissue the spaces of the network are more rounded: in papillary projections, like those of the skin, or mucous membranes, or placental villi, the capillaries are arranged in the form of loops, which either may, or may not, be united into a network.

The capillaries lie in the interstices between the proper tissues of the part or organ, and do not penetrate into the interior of the cells or fibres of which the tissues are composed. Organs vary considerably in their vascularity, and the vascularity of an organ depends upon the relative proportion of the capillaries that it contains to the proper substance of the tissue of the organ. The vascularity of an organ is in relation to its degree of functional activity, and in infancy and youth when parts are actively growing, their vascularity is greater than in adult life, when the growth has ceased. Some structures, as adult cartilage, the cornea, epithelium, hairs, nails, cuticle, and endothelium, have no capillaries passing into their substance, and are therefore non-vascular.

THE VEINS.

The veins are the vessels which convey the blood from the capillaries back to the heart, and in their course increase in size, by junction or anastomosis with each other. The rootlets of the veins spring from a network of capillary vessels; they communicate with each other and form a venous plexus, from which larger veins arise. The veins in the body are more numerous than the arteries, and possess collectively a greater capacity than the arteries. In most of the veins delicate valves are found, which possess a semilunar form, and are usually arranged in pairs, and a pouch-like dilatation of the wall of the vein is opposite each segment of the valve. When the blood flows along the veins towards the heart, the valves lie against the wall of the vessel; but if pressure be applied

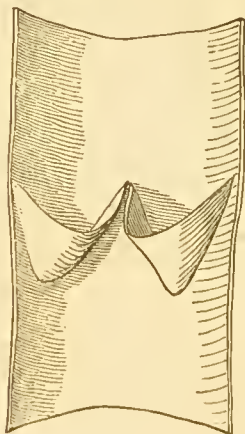


FIG. 136.—A Vein cut open to show a pair of valves.

to a vein so as to obstruct the onward flow of the circulation, then the blood passes into the pouches between the wall of the vein and the valve adjacent to the seat of pressure, so as to force the segments of the valve across the lumen of the vein and stop the regurgitation of the blood. The valves are found especially in the veins of the limbs, where the circulation is likely to be interfered with either by the pressure of the muscles on the veins during their action, or

by the pressure of blood caused by gravity, and are usually seated at the points of confluence of veins.

They are absent in the veins of the lungs, of the brain, in the *venæ cavæ* and hepatic vein, and in the veins of several of the abdominal viscera. Some of the veins lie in the subcutaneous fat, and are called *superficial veins*, others lie amidst the muscles, and form the *deep veins*. The deep veins usually accompany the arteries, and are named after them; in many localities an artery is accompanied by two veins, termed its *venæ comites*. Some of the deep veins, as the cranial venous sinuses, do not however run along with arteries. The superficial veins do not accompany arteries. Frequent anastomoses take place between the superficial and deep veins.

The veins are arranged primarily into two groups—the Pulmonary veins and the Systemic veins.

PULMONARY GROUP OF VEINS.

The pulmonary group of veins consists of the veins which convey the arterial blood from the lungs to the left auricle of the heart.

TWO PULMONARY VEINS are formed in each lung by the coalescence of the venous radicles, which arise from the pulmonary capillary plexus. They run to the root of the lung, where they are placed anterior to the pulmonary artery and bronchial tube, and end by opening into the back of the left auricle. The pulmonary veins anastomose with each other in the substance of the lung. They are devoid of valves, and do not possess a greater capacity than the pulmonary arterics.

SYSTEMIC GROUP OF VEINS.

The Systemic group of veins consists of the coronary venous system; the system of the superior vena cava; the system of the inferior vena cava; and associated with the inferior vena cava is the portal venous system.

Coronary Venous System.

The Coronary venous system consists of the veins of the heart, or the cardiac veins.

The CARDIAC VEINS arise from the capillaries of the coronary arteries in the substance of the muscular wall of the heart. Those which arise in the ventricles run on the anterior and posterior surfaces, from the apex to the auriculo-ventricular groove, where they open into the *great coronary vein*, and possess valves at their orifices. This vein runs in that groove on the back of the heart, where it dilates into a sinus—the *coronary venous sinus*—which opens into the right auricle, between the mouth of the inferior cava and the right auriculo-ventricular orifice. Veins from the wall of the left auricle open into the great coronary vein, but the veins from the wall of the right auricle for the most part open directly into its cavity at the foramina Thebesii. One vein which passes obliquely from the wall of the left auricle into the sinus is the remains of the left superior vena cava of the embryo.

System of the Superior Vena Cava.

The SUPERIOR OR DESCENDING VENA CAVA collects and conveys to the right auricle of the heart the blood which circulates in the head, neck, upper limbs, and the walls of

the chest. It is situated in the cavity of the thorax, and is formed by the junction of the two brachio-cephalic veins, about opposite the sternal end of the first intercostal space. It descends on the right of the ascending aorta, pierces the fibrous layer of the pericardium, and opens into the upper and posterior part of the right auricle. Immediately above the pericardium it is joined by the azygos vein (fig. 137). No valve exists either in its course or at its auricular orifice.*

The Azygos vein collects the blood which has been conveyed by the intercostal arteries to the posterior part of the walls of the chest. It consists in the lower part of the thorax of two veins, the right and the left azygos. The *right azygos*, or *azygos major*, is connected below with the right lumbar veins of the wall of the abdomen; it enters the thorax through the aortic opening in the diaphragm, ascends on the bodies of the dorsal vertebræ to the right of the thoracic duct and the descending thoracic aorta, and receives in its course the series of right intercostal veins. Opposite the 6th or 7th dorsal vertebræ it is joined by the *left azygos* vein, and higher in the thorax it receives the *oesophageal* veins, the *right bronchial vein*,

* As an exception to this statement, I may mention that in the year 1868 I dissected the heart of a man in which a semilunar valve was placed at the mouth of the superior cava. Shortly afterwards P. D. Handyside published an account of the heart of a male fœtus, æt 6½ months, in which a semilunar valve was present at the auricular orifice of the superior cava. In 1839 A. F. J. C. Mayer described two semilunar valves situated close together in the anterior cava of the dromedary. Vulpian and Philipeaux had seen a valve at the mouth of the right anterior cava in the heart of the elephant, and a similar observation was afterwards made by one of my former assistants, M. Watson, on an elephant's heart dissected in the practical anatomy rooms of the University of Edinburgh.

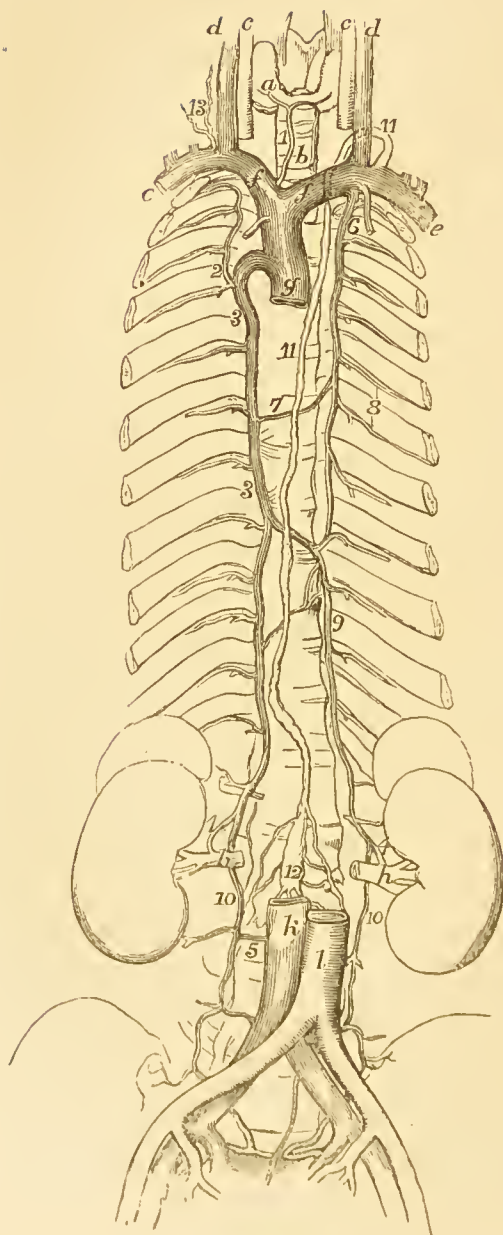


FIG. 137.—The Great Systemic Veins. *a*, thyroid body; *b*, trachea; *c*, *c*, common carotid arteries; *d*, *d*, internal jugular veins; *e*, *e*, subclavian veins; *f*, *f*, innominate veins; *g*, superior vena cava; *h*, *h*, renal veins; *k*, inferior vena cava; *l*, abdominal aorta. 1, inferior thyroid vein; 2, right superior intercostal vein; 3, 3, vena azygos; 4, origin of vena azygos from right renal vein, and from lumbar vein 5; 6, left superior intercostal vein; 7, communicating branch with vena azygos; 8, 8, intercostal veins; 9, lesser vena azygos; 10, origin from renal and lumbar veins; 11, 11, thoracic duct; 12, receptaculum chyli; 13, right lymphatic duct.

and sometimes the *right superior intercostal* vein. When on a level with the upper border of the root of the right lung, the azygos vein arches forwards above the root and joins the superior cava. The *left azygos*, or *azygos minor*, is connected below with the left lumbar veins, or the left renal; it enters the thorax through the aortic opening in the diaphragm, ascends in front of the bodies of the lower five or six dorsal vertebræ, receives the corresponding intercostal veins, and runs behind the aorta to join the right azygos vein. Owing to the connection below of the azygos veins with the lumbar veins, the systems of the superior and inferior venæ cavæ are anatomically continuous with each other (fig. 137). The azygos vein is provided with valves.

The intercostal veins of the two or three upper spaces of the right side join to form the *right superior intercostal* vein, which opens into the right brachio-cephalic vein, though sometimes they join the azygos vein. The intercostal veins of the upper four or five spaces of the left side join to form the *left superior intercostal* vein, which usually opens into the left brachio-cephalic vein, though it may join the left azygos vein. The *left bronchial* vein ends in the left superior intercostal vein.

The BRACHIO-CEPHALIC or INNOMINATE veins are two in number, a right and a left. Each is formed by the junction, opposite the inner end of the clavicle, of the subclavian and internal jugular vein of its own side. The right vein is short, and descends to the right of the arteria innominata as far as the sternal end of the first intercostal space, where it is joined by the left brachio-cephalic vein to form the superior cava. The *left* vein, much longer than the right, crosses obliquely

from left to right behind the manubrium sterni, between it and the three great arteries arising from the transverse part of the aortic arch. These veins have no valves. Each brachio-cephalic vein has opening into it : *a*, the *inferior thyroid* vein, which descends from the thyroid body, in front of and by the side of the trachea, and receives the *inferior laryngeal* vein : *b*, the *internal mammary* vein, which is formed by the junction of the venæ comites of the internal mammary artery ; these venæ comites receive small veins corresponding to the several branches of the artery : *c*, the *superior intercostal* vein, except in those cases in which this vein joins the azygos (fig. 137).

The subclavian vein is a large trunk, formed by the junction of the superficial and deep veins of the upper limb, which are arranged as follows :—

The *superficial* veins of the hand commence at the tips and sides of the fingers, from whence they proceed to the back of the hand, beneath the skin of which they may be distinctly seen. They then ascend along the fore-arm, forming three large veins : the *radial*, on the outer side ; the *ulnar*, on the inner ; and the *median*, in the middle of the front of the fore-arm. At the bend of the elbow the median divides into two branches, of which one, named *median-cephalic*, joins the radial to form the *cephalic* ; the other, named *median-basilic*, joins the ulnar to form the *basilic* vein. Into one or other of these two branches the surgeon generally makes an opening when he is desirous of drawing blood from the veins of the arm. The cephalic vein ascends along the upper arm, and a little below the clavicle pierces the fascia to join the axillary vein. The basilic pierces the fascia about the middle of the upper arm, and joins the

brachial veins to form the axillary vein. The communications between the superficial and deep veins are not, however, confined to the point of termination of the former, but occur at various parts of their course, more especially at the bend of the elbow, where a *deep median* vein connects the median with the deep veins of the fore-arm.

The *deep* veins of the hand commence at the tips of the fingers, and pass as *digital* veins on the sides of the fingers to the palm of the hand, in which two venous arches, corresponding to the arterial arches of the palm, are situated; from these arches the veins extend upwards along the front of the fore-arm, as far as the bend of the elbow; two veins closely accompanying each of the arteries of the fore-arm, and receiving numerous small veins corresponding to the branches of these arteries. At the bend of the elbow two *brachial* veins result from the junction of the *deep radial* and *deep ulnar* veins of the fore-arm. The *brachial* veins pass up the inner side of the upper arm, closely accompanying the brachial artery as far as the arm-pit, where they join to form, along with the superficial basilic vein, a single large axillary vein: they receive in their course small veins which correspond to the branches of the brachial artery.

The AXILLARY vein is a large vessel which ascends to the inner or thoracic side of the axillary artery, and passes behind the clavicle and the subclavius muscle, to become the subclavian vein. It receives not only the veins which correspond to the branches of the axillary artery, but, just before passing behind the subclavius muscle, it is joined by the superficial *cephalic* vein. Valves occur in it and in the other veins in the upper limb.

The SUBCLAVIAN vein is the direct continuation of the axillary; it courses upwards and inwards across the root of the neck, and joins the internal jugular, to form the brachio-cephalic vein. It lies anterior and inferior to the subclavian artery, and rests in a groove on the upper surface of the first rib, in front of the scalenus anticus muscle, which separates it at that spot from the artery. It receives the *vertebral* vein, which descends at the side of the vertebral artery, in the vertebrarterial foramina in the transverse processes of the cervical vertebræ, as far as the sixth vertebra, and then enters the subclavian vein: it receives various *spinal* veins and the *deep cervical* vein.

The subclavian vein also receives two of the superficial veins of the neck, the *anterior* and *external jugular* veins.

The ANTERIOR JUGULAR vein commences by the junction of small rootlets in the superficial fascia of the submaxillary region: it descends close to the anterior middle line of the neck, and joins either the subclavian vein directly, or the external jugular vein. The opposite anterior jugulars are frequently connected together by a transverse branch which passes across the middle line, above the sternum, and superficial to the trachea.

The EXTERNAL JUGULAR vein commences in the substance of the parotid gland, by the junction of the temporal, internal maxillary, transverse facial, posterior auricular, and sometimes the occipital veins, all of which correspond to branches of the external carotid artery. It passes obliquely downwards and backwards under the platysma; but superficial to the cervical fascia and sterno-mastoid muscle, and a little above the clavicle, pierces the fascia and enters the sub-

clavian vein : after it has pierced the fascia, it receives the *suprascapular* and *transversalis colli* veins corresponding to those branches of the subclavian artery. A bisegmented valve occurs in the course of the external jugular vein, and a similar valve at its junction with the subclavian. J. Struthers has shown that the *transversalis colli* and *suprascapular* veins possess valves, but not the anterior jugular : also that no valves occur in the subclavian vein, except immediately external to the point of entrance of the external jugular ; but at the junction with the brachio-cephalic vein a two segmented valve is found.

The INTERNAL JUGULAR vein is the large vein which collects the blood from the brain, the face, and certain parts of the neck. It begins at the jugular foramen, where it is continuous with the lateral cranial blood sinus in the dura mater, and descends to the outer side of the internal carotid and the common carotid arteries, but within the same sheath ; behind the inner end of the clavicle, it joins the subclavian vein, to form the brachio-cephalic vein. J. Struthers has described a bi-segmented valve as constantly present, either at or close to the mouth of the internal jugular vein. It receives—

a. The *Facial* vein, which runs down the side of the face, posterior to and a little distance from the facial artery, and enters the internal jugular a little below the posterior belly of the digastric muscle : the facial vein is joined by the veins which correspond to the branches of the facial artery, as well as by the *frontal* vein from the forehead. A *communicating* vein connects the facial with the temporal veins, and, in cases where the external jugular vein is small, allows the blood from the veins,

corresponding to the cranial branches of the external carotid artery, to flow into the internal jugular vein.

b. The *Lingual* vein conveys the blood from the tongue into the internal jugular vein.

c. The *Pharyngeal* vein corresponds to the ascending pharyngeal artery, and joins the internal jugular.

d. The *Occipital* vein sometimes joins the internal, at others the external jugular vein.

e. The *Superior Thyroid* vein proceeds from the thyroid body, and is joined by the *superior laryngeal* vein before it enters the internal jugular.

f. A *Middle Thyroid* vein is sometimes seen passing from the thyroid body to the internal jugular vein.

THE CRANIAL VENOUS BLOOD SINUSES are veins situated between two layers of the dura mater lining the interior of the cranial cavity. Their general arrangement has been described in the section on the membranes of the brain, p. 217. It may, however, be further stated that these sinuses are situated, some in the mesial plane of the cavity, as the *superior longitudinal* sinus, *inferior longitudinal* sinus, *straight* sinus and *occipital* sinus : others laterally to that mesial plane, as the *cavernous* sinus, the *superior* and *inferior petrosal* sinuses and the *lateral* sinus : others across the mesial plane, as the *circular* sinus, which courses around the pituitary body, and opens on each side into the cavernous sinus lying at the side of the body of the sphenoid bone ; and the *transverse* sinus which passes across the upper surface of the basi-occipital and connects the two inferior petrosal sinuses (figs. 138, 139). The cranial blood sinuses receive blood from the brain, orbit, and veins of the diploë of the cranial bones, also small veins from the

dura mater immediately adjacent to each sinus. They are without valves; but the superior longitudinal sinus has an irregular inner surface, owing to the projection of fibrous bands into its lumen.

The VEINS OF THE BRAIN ramify in the pia mater, and are arranged in a superficial and a deep group:—

The *superficial* veins of the cerebrum pass out of the convolutions into the pia mater covering the outer surface

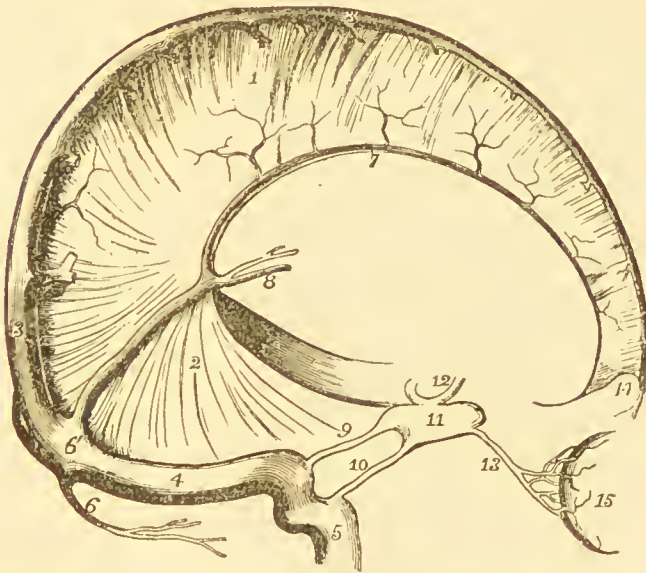


FIG. 138.—Dura mater and Cranial Sinuses. 1, Falx cerebri; 2, tentorium; 3, 3, superior longitudinal sinus; 4, lateral sinus; 5, internal jugular vein; 6, occipital sinus; 6', torcular Herophili; 7, inferior longitudinal sinus; 8, veins of Galen; 9 and 10, superior and inferior petrosal sinuses; 11, cavernous sinus; 12, circular sinus, which connects the two cavernous sinuses together; 13, ophthalmic vein from 15, the eyeball; 14, crista galli of ethmoid bone.

and the inner face of the cerebral hemispheres, and open into the superior longitudinal sinus, though some of the veins of the inner face open into the inferior longitudinal sinus. The veins from the convolutions on the lateral and under surfaces of the cerebrum open into the cavernous,

petrosal and lateral sinuses. The veins of the upper surface of the cerebellum open into the straight sinus, those of the under surface into the lateral and occipital sinuses.

The *deep* veins of the cerebrum emerge from the corpora striata and optic thalami, enter the choroid plexuses which form the fringe of the velum interpositum, and converge to the middle of the velum, where they form the two veins of Galen. The *veins of Galen* run backwards close to the mesial line of the velum, and passing along with it through the transverse fissure of the cerebrum below the posterior end of the corpus callosum, reach the tentorium cerebelli, and enter the straight sinus.

The OPHTHALMIC veins are two in number, a *superior* and an *inferior*. They are situated in the orbit, and are formed by the union of a number of small veins corresponding to the branches of the ophthalmic artery. The superior vein passes backwards through the sphenoidal fissure, and opens into the cavernous sinus. The inferior vein may have the same course, but more usually it goes through the sphe-no-maxillary fissure, and joins a plexus of veins in the pterygoid region, which serves as a rootlet for the internal maxillary vein. The *vena centralis retinae* usually opens directly into the cavernous sinus. The superior ophthalmic vein communicates with the veins of the forehead and with the *angular* vein, one of the rootlets of the facial vein, at the inner angle of the orbit.

The VEINS OF THE DIPLOË are contained in canals in the diploë of the cranial bones ; those which lie in the parietal and occipital bones communicate not only with the lateral and occipital sinuses, but with the temporal and occipital

veins, whilst the veins in the diploë of the frontal bone open into the frontal or supra-orbital vein.

Though the intra-cranial blood for the most part leaves the skull through the lateral sinuses and internal jugular

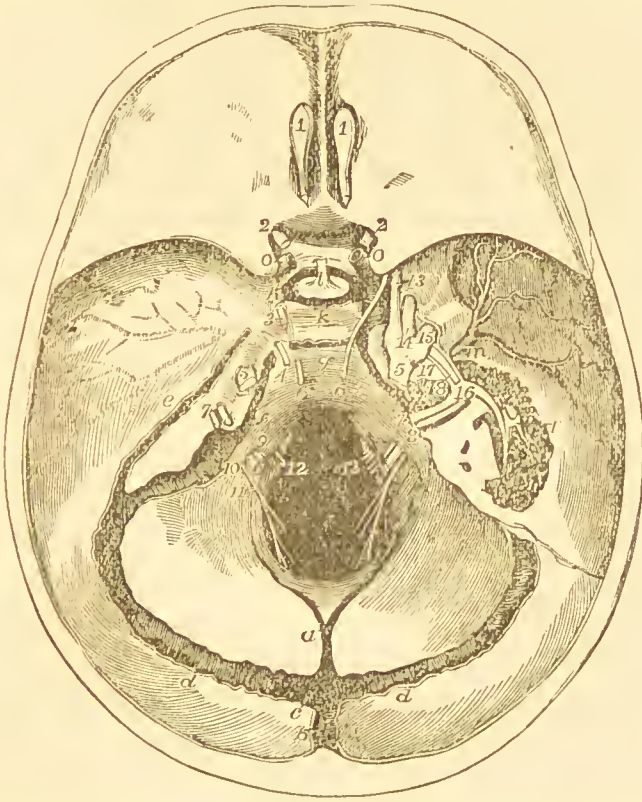


FIG. 139.—Floor of the cavity of the skull to show the Cranial Nerves and Blood Sinuses. 1 to 6, first to sixth cranial nerves; 7, portio dura; 8, portio mollis; 9, glosso-pharyngeal; 10, pneumogastric; 11, spinal accessory; 12, hypo-glossal; 13, 14, 15, first, second, and third divisions of fifth nerve; 16, knee-shaped ganglion of portio dura; 17 and 18, great and small superficial petrosal nerves; *a*, ocellipital sinus; *b*, superior longitudinal; *c*, torcular Herophili; *d*, lateral sinus; *e*, superior, and *f*, inferior petrosal sinus; *g*, transverse sinus; *h*, cavernous sinus; *k*, circular sinus; *l*, pituitary body; *m*, middle meningeal artery, *n, n*, bones of the ear; *o, o*, internal carotid artery.

veins, yet certain accessory communications exist between the cranial sinuses and the veins on the outside of the head. Thus the superior longitudinal sinus communicates

with the veins in the parieto-occipital region of the scalp by two small *emissary* veins, which pass through the parietal foramina; and each lateral sinus communicates with the veins at the back of the head through the *emissary* veins which pass through the mastoid and the posterior condyloid foramina. Nuhn has described *emissary* veins, continuous with the cavernous sinus, as passing through the foramen ovale in the sphenoid to become continuous with the middle meningeal vein; Henle states that a similar vein goes through the foramen lacerum; and Rektorzik has recorded a similar vein descending through the carotid canal in the petrous bone. The occipital sinus communicates with the posterior spinal plexuses of veins; the inferior cerebellar veins, or the petrosal sinuses, join the venous plexus surrounding the upper end of the spinal cord. The superior ophthalmic vein, by its communication, on the one hand with the cavernous sinus, and on the other with the veins of the face and forehead, connects the intra-cranial with the extra-cranial venous systems. Seseman maintains that, whilst the blood of the superior ophthalmic vein may flow into the cavernous sinus, yet that its chief outlet is into the facial vein. The *middle meningeal* veins arise in the dura mater, and leave the skull through the foramen spinosum to serve as rootlets for the internal maxillary vein.

THE VEINS OF THE SPINE are arranged in relation to both the spinal column and the spinal cord.

The *Veins of the Spinal Column* ramify on the exterior of the vertebræ, in the substance of the vertebral bodies, and in the interior of the spinal canal. The *extra-spinal* or *dorsal veins* form a plexus on the back of the neural

arches and spines. The *veins of the bodies* of the *vertebræ* lie in canals in the spongy substance of the vertebral bodies, and leave the bone through foramina on its surface, of which the one that opens on the posterior surface of the body is the best marked. The veins within the spinal canal lie in the fatty tissue which separates the dura mater from the bony walls of the canal, and are arranged in an anterior and a posterior longitudinal group; the *anterior longitudinal spinal* veins lie behind the bodies of the *vertebræ* in the whole length of the spinal canal; the *posterior longitudinal spinal* veins form a plexus in the whole length of the canal immediately in front of the neural arches.

The *Veins of the Spinal Cord* ramify in the pia mater investing the cord, in which they form plexuses.

The spinal veins freely anastomose with each other. The veins of the cord communicate with the veins within the canal through small veins, which run with the nerve roots to the foramina in the dura mater, through which the roots proceed; whilst at the upper end of the canal they join the vertebral and the inferior cerebellar veins, and perhaps the petrosal sinuses. The veins of the vertebral bodies communicate with the anterior longitudinal veins. The anterior longitudinal communicate with the posterior longitudinal veins, with which they form a venous plexus; this plexus is united to the dorsal spinal veins by veins, which pierce the ligamenta subflava, and pass between the vertebral laminæ; it freely communicates also with the lumbar veins, the intercostal veins, and the vertebral veins, by veins which pass outwards through the intervertebral foramina.

System of the Inferior Vena Cava.

The INFERIOR or ASCENDING VENA CAVA collects and conveys to the right auricle of the heart the blood which circulates in the lower limbs, in the abdominal and pelvic walls and viscera. It is chiefly situated in the cavity of the abdomen, and is formed by the junction of the two common iliac veins on the right side of the body of the fifth lumbar vertebra (fig. 140); it ascends to the right, close to the abdominal aorta, for some distance; when it reaches the under surface of the liver it lies in a fossa in that organ, and is separated from the aorta by the right crus of the diaphragm; it then pierces the tendon of the diaphragm and the fibrous layer of the pericardium, and opens into the lower and posterior part of the right auricle. Except the Eustachian valve at its auricular orifice, it is without valves.

Several veins, corresponding to branches of the abdominal aorta, open directly into the inferior vena cava; as follows:—

The MIDDLE SACRAL vein joins either the commencement of the cava, or the left common iliac vein.

The LUMBAR veins collect the blood from the posterior wall of the abdomen, and open into the posterior wall of the inferior cava. As already described (pp. 503, 505), these veins also communicate with the azygos vein.

The SPERMATIC veins ascend from the testicles, one in each spermatic cord, in which it forms a plexiform arrangement. At the internal or deep abdominal ring it runs upwards behind the peritoneum and opens on the right side into the inferior cava, on the left into the left renal vein.

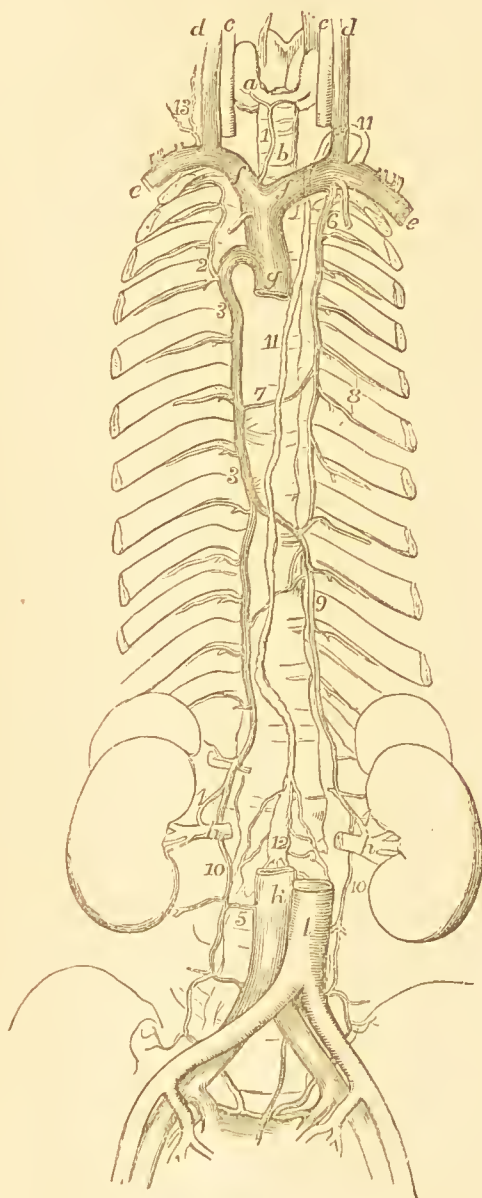


FIG. 140.—The Great Systemic Veins, *a*, thyroid body; *b*, trachea; *c, c*, common carotid arteries; *d, d*, internal jugular veins; *e, e*, subclavian veins; *f, f*, innominate veins; *g*, superior vena cava; *h, h*, renal veins; *k*, inferior vena cava; *l*, abdominal aorta. 1, inferior thyroid vein; 2, right superior intercostal vein; 3, 3, vena azygos; 4, origin of vena azygos from right renal vein, and from lumbar vein 5; 6, left superior intercostal vein; 7, communicating branch with vena azygos; 8, 8, intercostal veins; 9, lesser vena azygos; 10, origin from renal and lumbar veins; 11, 11, thoracic duct; 12, receptaculum chyli; 13, right lymphatic duct.

They possess valves, and, according to Rivington, both spermatic veins have usually valves at their orifices.

In the female the OVARIAN veins ascend from the ovaries and terminate like the male spermatic veins. They form in each broad ligament a plexus, which anastomoses with the veins of the uterus. Rivington observed their valves to resemble in arrangement those of the spermatic veins.

The RENAL veins pass almost transversely, one from the hilus of each kidney, into the sides of the vena cava. The left renal vein is longer than the right, and crosses in front of the abdominal aorta. Crisp and Rivington have observed valves in these veins, especially where they join the inferior cava.

The SUPRA-RENAL or CAPSULAR veins lie just above the renal, and proceed from the supra-renal capsules ; the right opens into the inferior cava, the left into the left renal, or sometimes the phrenic vein.

The PHRENIC veins open into the inferior cava, close to the diaphragm.

The HEPATIC veins arise in the substance of the liver from the capillaries of the lobules ; they converge to the fossa in which the inferior cava is situated, and open into it.

The COMMON ILIAC vein is formed by the junction of the external and internal iliac veins. It commences near the sacro-iliac joint, and ascends to the level of the disc between the fourth and fifth lumbar vertebræ, when it joins its fellow to form the inferior vena cava. As the junction takes place to the right of the mesial plane, the right vein is shorter than the left, and ascends nearly vertically behind, and then to the outer side of the right

common iliac artery ; the left vein is at first to the inner side of its artery, and then ascends behind the right common iliac artery.

The INTERNAL ILIAC vein is formed in the cavity of the pelvis by the junction of a number of veins which correspond to the branches of the internal iliac artery. It lies in front of the sacro-iliac joint, and opposite the brim of the pelvis joins the external iliac to form the common iliac vein. The iliac veins are without valves.

The veins which correspond to the visceral branches of the internal iliac artery form, in relation with their respective viscera, complicated venous plexuses. The *prostatic venous plexus* surrounds the prostate gland, and receives at its anterior part the *dorsal vein* of the penis, which enters the pelvis by piercing the sub-pubic ligament and does not end in the deep pudic vein. The prostatic plexus communicates behind with the *vesical venous plexus*, which is arranged on the outer aspect of the muscular coat of the bladder, and is especially well marked at the base of the bladder. The vesical and prostatic plexuses communicate with the *hæmorrhoidal venous plexus*, which is arranged in and around the wall of the lower end of the rectum and anal orifice. The hæmorrhoidal plexus communicates with the superior hæmorrhoidal vein, which forms one of the rootlets of the portal system of veins ; it also gives rise to the middle and inferior hæmorrhoidal veins, which join the deep pudic vein of the internal iliac, and is thus brought into connection with the system of the inferior vena cava. In the female a *vaginal venous plexus* surrounds the wall of the vagina, and a *uterine venous plexus* is arranged on and in the wall of the uterus, and between

the two layers of the broad ligament. The several venous plexuses in relation to the pelvic viscera are apt to become enlarged and gorged with blood, especially in old people, and the veins of the lower end of the rectum and around the anus are apt to undergo varicose dilatations, named hæmorrhoids or piles.

The EXTERNAL ILIAC vein is directly continuous with the femoral vein, ascends in close relation to the external iliac artery, and joins the internal iliac to form the common iliac vein. It receives immediately above Poupart's ligament the *deep epigastric* and *deep circumflex iliac* veins.

The FEMORAL vein is formed by the union of the superficial and deep veins of the lower limb, which are arranged as follows :—The superficial veins of the dorsum of the foot are separated from the deep veins by the deep fascia. They commence by very fine rootlets arising from the capillaries of the skin. At the sides of the toes they form the *digital* veins, and on the dorsum of the foot the digital veins form an arch, from the inner side of which a vein, called the *long saphenous*, arises. This passes upwards along the inner side of the leg and thigh, increasing considerably in size in its course, owing to a number of veins joining it from the extensive surface of the skin of the limb. It terminates, at the upper part of the thigh, by passing through the saphenous opening in the fascia lata, and joins the femoral vein. From the outer side of the venous arch on the dorsum of the foot arises the *external saphenous* vein, which runs behind the outer ankle and on the back of the leg to the ham, where it pierces the popliteal fascia to join the popliteal vein. The deep veins begin both on

the dorsum of the foot and in the sole. Those which arise on the dorsum of the foot form the *anterior tibial* veins, and accompany the anterior tibial artery; they receive a considerable number of branches in their upward course, which proceed from the mass of muscles lying on the front of the leg. The veins which begin in the sole of the foot accompany the plantar arteries, form the *plantar* veins, and then pass upwards, along the inner ankle, to reach the back of the leg, along which they ascend as the *posterior tibial* veins, closely accompanying the posterior tibial artery, and receiving in their course numerous small veins that proceed from the muscles of the back of the leg, and the *peroneal* veins. At the upper part of the leg the anterior tibial veins pass to the back of the leg, and join the posterior tibial veins. The large *popliteal* vein, formed by their junction, ascends behind the knee-joint, lying in the ham, along with the popliteal artery. At the upper part of the popliteal space it passes to the inner side of the thigh, ascends as the *femoral* vein, alongside of the femoral artery, as far as Poupart's ligament, when it enters the cavity of the abdomen and becomes the *external iliac* vein. At the upper part of the thigh the femoral receives the *profunda* vein, corresponding to the profunda artery of the thigh, which conveys the blood that has been carried by that artery to the numerous large and important muscles of the thigh. The femoral vein is also joined near this spot by the superficial long saphenous vein, into which the *superficial epigastric*, *pubic* and *circumflex iliac* veins open immediately before its termination. Valves exist in the femoral and the other veins in the lower limbs.

The Portal Venous System.

The portal system of veins is supplementary to the system of the inferior vena cava, and is formed by the veins of the intestine, which correspond to the inferior and superior mesenteric branches of the abdominal aorta, and by veins corresponding to the branches of the cœliac axis which go to the stomach, spleen, pancreas, and gall bladder. It collects and conveys the blood from those viscera and from the several divisions of the intestinal tube (fig. 141).

The INFERIOR MESENTERIC vein arises, as the *superior hæmorrhoidal* vein, from the hæmorrhoidal plexus of veins around the lower end of the rectum ; it ascends behind the rectum, and is then joined by the *sigmoid* vein. In its further ascent the inferior mesenteric receives the *left colic* vein, and lies behind the peritoneum to the left of the inferior mesenteric artery ; it then passes behind the pancreas and ends in the splenic vein.

The SUPERIOR MESENTERIC vein is formed by the junction of the *ileo-colic*, *right colic*, and *middle colic* veins ; it receives the *intestinal* veins corresponding to the intestinal branches of the superior mesenteric artery and the *right gastro-epiploic* vein. It ascends in the mesentery to the right side of the superior mesenteric artery, goes in front of the duodenum, and behind the pancreas, to join the splenic vein and so form the portal venous trunk (fig. 141).

The SPLENIC vein commences in the substance of the spleen, from which it emerges at the hilus in five or six divisions, which unite in the gastro-splenic omentum into a single vein. The splenic vein runs to the right along with the splenic artery and behind the pancreas, and joins

the superior mesenteric vein to form the portal venous trunk. It receives in its course the *short gastric* vein from the stomach, the *left gastro-epiploic* vein, *pancreatic* and *duodenal* veins, and the *inferior mesenteric* vein. E. Crisp has described valves in both the splenic and mesenteric veins.

The CORONARY vein runs along the small curvature of the stomach and joins the portal venous trunk near its origin.

The CYSTIC vein proceeds from the gall bladder, and joins either the portal venous trunk near the liver, or its right branch of bifurcation.

The PORTAL VENOUS TRUNK, or PORTAL VEIN, is formed by the union, behind the pancreas, of the splenic and superior mesenteric veins. It passes obliquely upwards and to the right, between the two layers of the small omentum, behind and between the hepatic artery and common bile duct, to reach the transverse fissure of the liver, where it divides into a right and a left branch. These branches enter the right and left lobes of the liver, in which they divide and subdivide after the manner of an artery, and end in the intra-lobular capillary plexus, from which the rootlets of the hepatic vein arise.

Although the portal venous system is sometimes regarded as distinct from the system of the inferior cava, except through the channel of communication provided by the hepatic vein, yet anastomoses between the two systems, do undoubtedly occur in connection with certain of their peripheral ramifications. It has already been stated (p. 519) that the hæmorrhoidal plexus is continuous with the rootlets of both systems. The elder Retzius observed

small veins from the duodenum opening into the inferior cava, also veins from the left colon opening into the renal

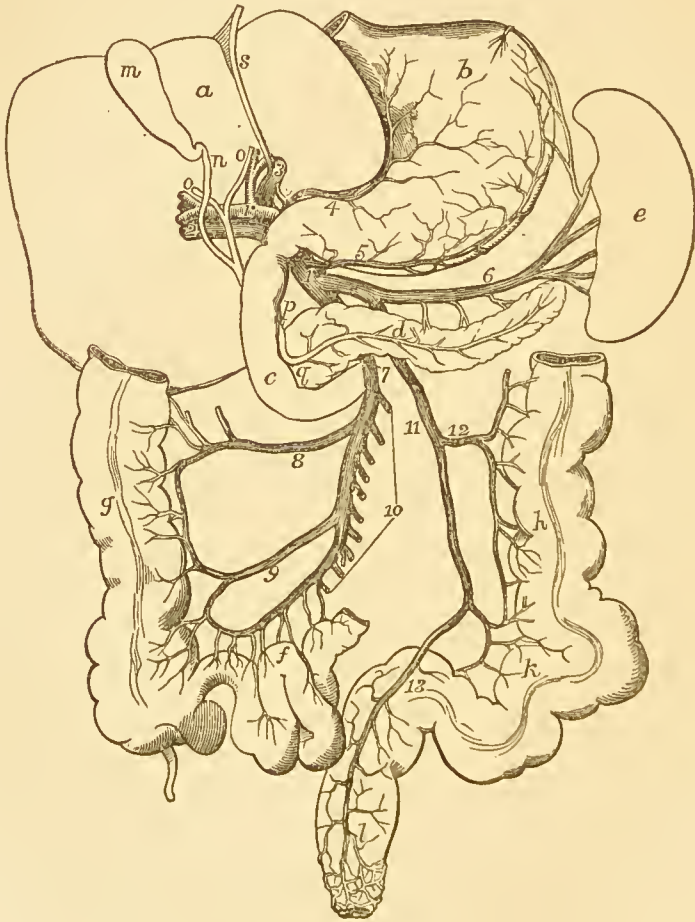


FIG. 141.—Diagram of the Portal Venous system. 1. Portal vein; 2 and 3, its right and left branches; 4, gastric vein; 5, right gastro-epiploic vein; 6, splenic vein; 7, superior mesenteric vein; 8 and 9, right and middle colic veins; 10, intestinal veins; 11, inferior mesenteric vein; 12, left colic vein; 13, superior hæmorrhoidal vein; a, liver; b, stomach; c, duodenum; d, pancreas; e, spleen; f, coils of small intestine; g, ascending colon; h, descending colon; k, sigmoid flexure; l, rectum; m, gall bladder; n, cystic duct; o, o, hepatic ducts; p, where common bile duct pierces wall of duodenum; q, pancreatic duct; r, hepatic artery; s, round ligament.

vein. Moreover, he described a network of small veins lying in the areolar tissue outside the peritoneum, which communicated on the one hand with the veins of the colon, and on the other with the renal veins, the pelvic veins, and other rootlets of the inferior vena cava. This network evidently corresponds with the extra-peritoneal arterial network, which I have injected and described in the same locality (p. 433), as connecting together the parietal and visceral branches of the abdominal aorta. Schiff and Luschka have also described, by the name of *vena parumbilicalis*, a small vein, which is connected on the one hand with the deep epigastric vein, a rootlet of the external iliac, and on the other with the portal vein; this vein ascends to the liver along with the round ligament. Cases of occasional enlargement of this vein have been described by Monro, Rokitansky, Champneys, and others. The inosculations described on p. 515 between the spinal veins and the lumbar and intercostal veins, establish a communication between the circulation in the spinal cord and that in the parietes of the chest and abdomen. These venous and arterial anastomoses have an interest and importance in connection with the practice of local blood-letting by cupping or leeching the abdominal wall.

Structure of the Veins.

Veins, like arteries, are enclosed in a fibrous sheath. The thickness of the wall of a vein is considerably less than that of an artery of equal size. The thinness of the venous wall enables the colour of the blood to be seen through it, so that veins have a bluish-purple colour. Veins have three coats,—an outer, middle, and inner.

The *outer* coat, or *tunica adventitia*, is formed by an interlacement of white and yellow elastic fibres of connective tissue; it possesses considerable strength, though it has no great thickness. In some veins, more especially those of the abdominal cavity, non-striped muscular fibres are found in this coat, arranged as a longitudinal network.

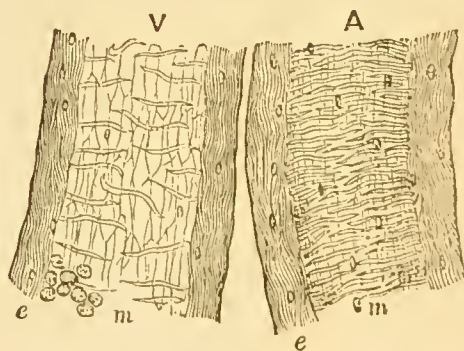


FIG. 142.—Structure of a Minute Artery A and Vein V. *e*, external coat or adventitia; *m*, transversely arranged muscular tissue of the middle coat. In the vein the endothelial lining may be seen through the thin middle coat. $\times 300$.

The *middle* coat consists of non-striped muscular fibres, arranged transversely around the vein, and mingled with these muscular fibres are white and yellow elastic fibres of connective tissue, which mostly run in a longitudinal

direction. This coat is much thinner than the middle coat of a corresponding artery ; but in some veins, especially those of middle size, it is thicker in proportion than in the largest sized veins. On the other hand, the veins of the pia mater, the venous sinuses in the dura mater, the veins of bones, of the retina, and the dilated veins of the corpora cavernosa, have no proper middle coat, and are without muscular fibres in their walls. In the smallest veins the venous rootlets, or *venules*, possess muscular fibres arranged transversely, but they are so scattered as not to form a continuous middle coat, and thus the venules present a marked contrast to the arterioles (fig. 142). Ranvier indeed considers that no definite middle coat exists in any of the veins, and that they have only an inner and an outer coat, in the latter of which non-striped muscular fibres, varying in number and direction, may be present.

The *inner* coat, or *tunica intima*, possesses a layer of endothelium next the lumen of the vein, the cells of which are polygonal scales, shorter and broader than those of an artery. Outside the endothelium is an extra-endothelial layer of connective tissue, and outside that again a network of elastic fibres, which does not possess the fenestrated character. This coat is not so thick as in the corresponding arteries. In the pulmonary vein it is said to contain non-striped muscular fibres. The valves of the veins are continuous with the inner coat ; they are covered by a layer of endothelium ; the cells on the surface of the valve, situated next to the lumen of the vein, are, according to Ranvier, elongated in a direction corresponding to the long axis of the vessel, whilst those on the opposite

surface of the valve are elongated transversely. Beneath the endothelium are bundles of connective tissue with elastic fibres, which are most distinct at the attached border of the valve.

Veins have not the elasticity of arteries, and do not pulsate. All veins which have muscular fibres in their coats are contractile. Veins, like arteries, possess vasa vasorum, and vaso-motor nerves are distributed to the muscular tissue in their walls. When a vein is empty or cut across, it does not gape like an artery, but collapses. H. Hoyer has recently pointed out that at the tip of the digits some of the small arterial twigs open directly into venous radicles, the communicating vessels being tortuous like a small glomerulus.

LYMPH-VASCULAR SYSTEM.

The lymph-vascular system is an appendage of, and supplementary to the blood-vascular system, and consists of small tubes or vessels, the Lymphatic Vessels, and of collections of Lymphoid or Adenoid Tissue, which form Lymphoid Organs. It is sometimes called the Absorbent System, as it plays an important though not an exclusive part in absorbing materials which have to be transmitted to the blood, but the blood capillaries themselves are also directly concerned in absorption.

LYMPHATIC VESSELS.

The Lymph Vessels, or Lymphatics, are tubes with delicate transparent walls, which convey the fluid called lymph and chyle. They arise, in the form of microscopic networks, in the connective tissue on the surface and in the substance of the parts and organs of the body, and they terminate by joining the large veins at the root of the neck, so that their contained fluid flows into the blood towards the heart. They resemble veins in having a course from periphery to centre; in possessing valves, which are generally two in number and semilunar in shape, and in being divided into *superficial* and *deep lymphatic* vessels. In the limbs and axial parts of the body the superficial lymphatics are situated, like the superficial veins, in the subcutaneous tissue; whilst the deep lymphatics accompany the arteries and deep veins. But the internal viscera also possess a superficial and a deep set of lym-

phatics, the superficial being situated next the investing coat of the organ, whilst the deep are situated along with the blood-vascular trunks in its substance. Lymphatics differ from veins in possessing in their course glandular enlargements, the lymph glands; in having thinner coats; in being almost uniform in size and much smaller than the veins; in not as a rule uniting into larger vessels as they pass onwards in their course; and in conveying lymph and not blood. They are for the most part fine thread-like tubes, and their main trunk, the thoracic duct, is not bigger than a crowquill. From the number of valves in these vessels, they present, when distended with fluid, a beaded or moniliform appearance. The lymph-vessels are divided into lacteal or chyle vessels and proper lymphatic vessels.

Distribution of the Lacteal or Chyle Vessels.

THE LACTEAL OR CHYLE VESSELS are limited to the intestine and its mesenteric folds, and are named from the milk-like chyle which they contain. They principally arise in the minute processes called *intestinal villi*, which project from the free surface of the mucous membrane of the small intestine into the canal of the bowel. The lacteals from adjacent villi unite and form a network in the submucous coat of the intestine, from which larger lacteals arise, which pierce the muscular coat. Immediately beneath the serous coat a longitudinal network exists, which communicates with the deeper lacteals. From these networks larger lacteals proceed, which enter the mesentery and ascend between its folds to its root of attachment at the posterior wall of the abdomen, where,

opposite the body of the first lumbar vertebra, they enter the receptaculum chyli or dilated commencement of the thoracic duct.

As the lacteals ascend in the mesentery they pass through a number of bodies, about the size of, or somewhat larger than, flattened peas, called the *mesenteric glands*, and as they unite in their ascent, they diminish in numbers and form larger vessels than when they emerged from the coats of the bowel.

Similar vessels, though fewer in number, arise in the mucous membrane of the large intestine, but not in intestinal villi. They also ascend to join the thoracic duct, and pass through glands similar to those within the mesentery.

Distribution of the Proper Lymphatic Vessels.

The Proper Lymphatic Vessels are situated in the other parts of the body than the intestine and its mesenteric folds. By their junction with each other they form two lymphatic trunks, named the thoracic duct and the right lymphatic duct.

The THORACIC DUCT commences in the cavity of the abdomen about opposite the body of the first or second lumbar vertebra, where it forms a dilatation, the *receptaculum chyli*, which receives not only the lacteal vessels, but the lymphatics from the other abdominal viscera, from the abdominal walls, and from the lower limbs. The thoracic duct passes through the opening in the diaphragm which transmits the aorta, ascends in front of the bodies of the dorsal vertebræ, at first to the right of the aorta, and

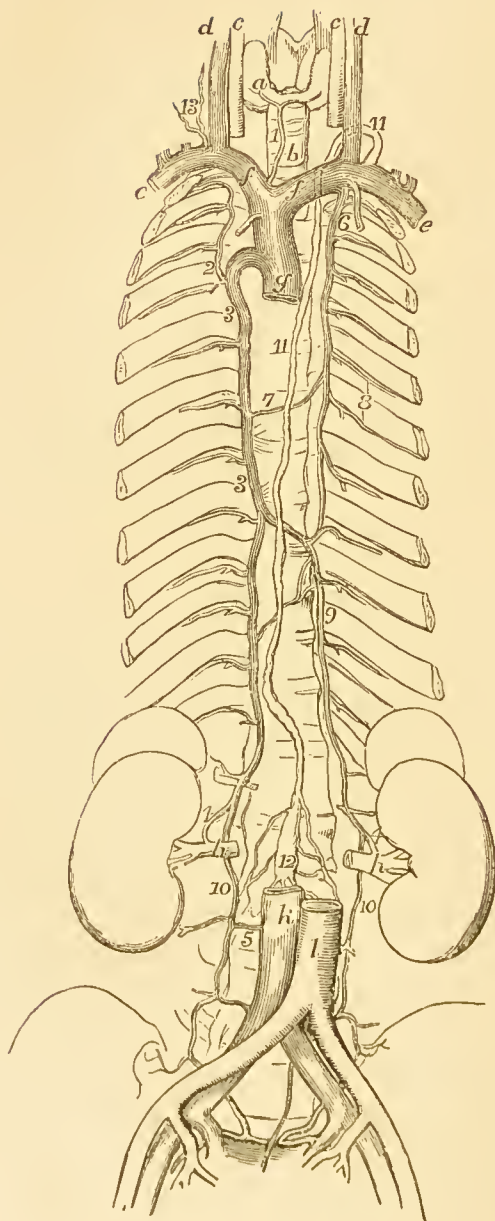


FIG. 143,—The Great Systemic Veins. *a*, thyroid body; *b*, trachea; *c, c*, common carotid arteries; *d, d*, internal jugular veins; *e, e*, subclavian veins; *f, f*, innominate veins; *g*, superior vena cava; *h, h*, renal veins; *k*, inferior vena cava; *l*, abdominal aorta. 1, inferior thyroid vein; 2, right superior intercostal vein; 3, 3, vena azygos; 4, origin of vena azygos from right renal vein, and 5, from lumbar vein; 6, left superior intercostal vein; 7, communicating branch with vena azygos; 8, 8, intercostal veins; 9, lesser vena azygos; 10, origin from renal and lumbar veins; 11, 11, thoracic duct; 12, receptaculum chyli; 13, right lymphatic duct.

then inclines behind the arch and reaches the left side of the œsophagus, at the side of which it ascends to the root of the left side of the neck. In its course in the thorax it receives the deep lymphatics of the left half of the chest, and at the root of the neck on the left side it is joined by the deep and superficial lymphatics of the left upper limb and left side of the head and neck, and opens into the internal jugular or the subclavian vein, or at the angle of junction between them. This duct conveys, therefore, the chyle during digestion, and the lymph contained in the lymph-vessels below the diaphragm and in the lymph-vessels situated to the left side of the mesial plane in the parts of the body above the diaphragm. The thoracic duct contains numbers of valves in its course, and a two-segmented valve occurs at its junction with the jugular vein, which prevents the blood from flowing from the vein into the duct.

The RIGHT LYMPHATIC DUCT is much smaller than the thoracic duct. It is situated on the right side of the root of the neck, and is formed by the junction of some of the lymph-vessels of the right half of the thoracic cavity, with those of the right upper limb and right side of the head and neck. It joins the great veins at the angle of union of the right internal jugular with the right subclavian, and a two-segmented valve, which prevents the flow of blood into it, is situated at its orifice.

The LYMPHATICS OF THE UPPER LIMB are arranged in a superficial and a deep set. The *superficial* lymph-vessels arise in the fingers as digital lymphatics, and from the

skin of the back of the hand and palm. From the hand they ascend to the fore arm, and then run along the upper arm to the axilla, where they enter the axillary glands. In the superficial fascia, immediately above the internal condyle of the humerus, one or two lymphatic glands are found in the course of the superficial lymph vessels.

The *deep* lymphatics ascend from the palm and accompany the radial, ulnar and interosseous arteries in the fore arm. In the upper arm they accompany the brachial artery, and with it enter the axilla. The *axillary lymph-glands*, about twelve in number, lie in the fat of the axilla, and to them the deep and superficial lymph-vessels of the upper limb proceed. Along the course of the deep brachial lymphatics some small lymphatic glands are sometimes seen. In addition to the lymph-vessels of the upper limb, the axillary glands receive superficial lymphatics from the anterior thoracic wall and the mammary gland, and the superficial lymphatics of the back. From the axillary glands lymph vessels proceed, which accompany the subclavian artery and join on the left side the thoracic duct, on the right side the right lymphatic duct.

The LYMPHATICS OF THE HEAD AND NECK are arranged in a superficial and a deep set. The *superficial* lymphatics of the face accompany the facial vein to the submaxillary region; whilst the superficial lymphatics of the cranium run along with the occipital and temporal blood-vessels to the back and side of the neck. *Deep* lymphatics accompany the internal maxillary vein from the deep parts of

the face ; deep lymphatics proceed from the pia mater and arachnoid membrane and leave the skull along with the internal jugular vein. In the neck *superficial* lymphatics are placed beneath the skin, and deep lymphatics proceed from the pharynx, larynx, tongue, &c. The lymphatics, both of the head and neck, converge towards the region of the sterno-mastoid muscle, and communicate with numerous cervical lymphatic glands arranged so as to form a chain connected by interglandular lymph-vessels, and termed the *glandulæ concatenatæ*. These glands lie under cover of the sterno-mastoid, and from their lower ends lymph-vessels proceed which join on the right side the right lymphatic duct ; on the left side the thoracic duct. Lymphatic glands occur in the submaxillary region, also superficial to the parotid gland, and in close relation to the occipital artery, where it pierces the trapezius to reach the back of the scalp.

The LYMPHATICS OF THE THORAX are situated in both the thoracic walls and in the viscera. The *superficial* lymphatics of the walls pass, as already stated, into the axilla, to enter the axillary glands. The *deep* lymphatics of the walls accompany the internal mammary and intercostal arteries, and in their course pass through lymphatic glands. Those which accompany the internal mammary arteries are in connection with the *sternal* or *anterior mediastinal glands*, and end on the right side in the right lymphatic duct, on the left side in the thoracic duct. Those which accompany the series both of right and left intercostal arteries end in the thoracic duct.

The *Lymphatics of the Lungs* form a *superficial* set

beneath the pleura, and a *deep* set accompanying the bronchus and the pulmonary blood-vessels. They pass from the lung at its root and enter the *bronchial glands*, which form a large cluster, both at the root of the lung and in the angle of bifurcation of the trachea. From the bronchial glands lymph-vessels proceed, which on the right side join the right lymphatic duct, on the left the thoracic duct.

The *Lymphatics of the Heart* accompany the coronary blood-vessels, and form at the base of the heart a right and a left trunk, each of which ascends in relation to the trachea; the right to end in the right lymphatic duct, the left in the thoracic duct. In their course they pass through lymphatic glands.

The *Lymphatics of the Œsophagus* are said to form only a single set, situated in the submucous coat; they leave the œsophagus and pass through lymphatic glands situated around the tube, and end in the thoracic duct.

The *Lymphatics of the Thymus* gland are numerous in infancy and childhood, and have been traced by Astley Cooper into the internal jugular veins.

THE LYMPHATICS OF THE ABDOMEN are situated in both the abdominal walls and in the viscera.

The *superficial* lymphatics of the anterior abdominal wall descend to join the *inguinal lymphatic glands* situated in the groin immediately below Poupart's ligament.

The *deep* lymphatics of the wall run along with the internal and external iliac arteries and their branches;

they have numerous *iliac lymphatic glands* connected with them. They ascend alongside of the aorta and inferior vena cava, passing through numerous *lumbar lymphatic glands* in their course, diminish in number but increase in size, and opposite the second lumbar vertebra unite to form the commencement of the thoracic duct. The iliac and lumbar lymphatic glands receive numerous lymph-vessels from the pelvic walls, the iliac fossæ, and the muscles of the loins.

The *Lymphatics of the Abdominal Viscera* proceed from the stomach, spleen, pancreas, liver, supra-renal capsules, kidneys, bladder, prostate gland, vesiculæ seminales and testicles, and in the female from the ovaries, uterus, and vagina.

In the *hollow viscera*, as the stomach and uterus, they are arranged in two sets, a *superficial* beneath the serous coat, a *deep* in the submucous coat. The lymphatics of the stomach leave that organ along with the blood-vessels; some join the lymphatics from the spleen, others the lumbar lymphatics, others one of the larger lacteals before it enters the receptaculum chyli. The lymphatics of the uterus receive those from the ovaries and vagina; whilst some accompany the ovarian arteries to join the lumbar lymphatic glands, others pass to the glands and lymph-vessels which accompany the internal iliac artery. The lymphatics of the bladder and vesiculæ seminales also enter the internal iliac glands and lymph-vessels.

In the *solid viscera* the lymphatics are arranged in two sets. The *superficial* are situated in relation to the tunica propria of the organ; the *deep* accompany the blood-vessels which pass into its substance. The lymphatics of

the pancreas join those from the spleen, and the splenic lymphatics accompany the splenic artery, and join the lumbar lymphatics. The lymphatics of the liver have different modes of termination; those from the upper surface communicate with the lymphatics which accompany the internal mammary arteries; those from the under surface join the commencement of the thoracic duct; whilst the deep lymphatics leave the liver at the transverse fissure and join one of the larger lacteals before it opens into the receptaculum chyli. The lymphatics of the supra-renal capsules join those of the kidneys, and the renal lymphatics open into the lumbar chain of lymphatic glands. The lymphatics of the testicles ascend along with the spermatic blood-vessels, and enter the lumbar chain of glands.

THE LYMPHATICS OF THE LOWER LIMB are arranged in a superficial and a deep set. The *superficial* lymph-vessels arise in the toes, and on the dorsal and plantar surfaces of the foot; they ascend to the leg, and accompany the internal and external saphenous veins. Those which run up the back of the leg in part pierce the popliteal fascia along with the external saphenous vein, and join the deep popliteal lymphatics; but the others extend to the inner side of the knee, and ascend along with the superficial lymphatics, which accompany the internal saphenous vein, on the anterior surface of the thigh as far as the groin, where they enter the femoral group of lymphatic glands. The *superficial glands* of the *groin* are eight or ten in number, and lie in the superficial fascia. It is customary to arrange them in two groups: an inferior, lying parallel

to the internal saphenous vein, named *femoral* glands, and a superior, lying parallel to and immediately below Poupart's ligament, named *inguinal* glands. The femoral glands receive the superficial lymph-vessels which ascend along the thigh. The inguinal glands receive the superficial lymph-vessels from the outside of the thigh, the anterior abdominal wall, and the organs of generation. From both sets of glands lymph-vessels proceed which perforate the fascia lata, at and near the saphenous opening, and join the deep lymphatics of the limb.

The *deep* lymph-vessels of the lower limb ascend from the sole and dorsum of the foot, along with the anterior and posterior tibial and the peroneal arteries. In the popliteal space they enter lymphatic glands situated in close relation to the popliteal artery. From these glands efferent vessels emerge, and ascend along with the femoral artery to reach the deep lymphatic glands of the groin, where they are joined by the efferent vessels from the superficial glands. They then ascend on the inner side of the femoral vein, through the crural canal, or innermost compartment of the femoral sheath, enter the abdominal cavity, and become continuous with the deep lymph-vessels and glands which accompany the external iliac artery.

Structure of the Lymphatic Vessels.

The lymphatic vessels consist of vessels that can be seen with the naked eye, and of lymph capillaries.

The *Larger Lymphatics* have in many respects the structure of veins, and like them possess three coats. The *outer* coat consists of white fibrous tissue, intermingled with elastic fibres, and a few bundles of non-striated mus-

cular fibre. The *middle* coat is formed of circularly arranged non-striped muscular fibre, intermingled with elastic fibres. The *inner* coat consists on its free surface of a layer of elongated, flattened, endothelial cells, outside which is a layer of elastic fibres arranged longitudinally. The valves of the lymphatics are simple folds of the inner coat. They usually consist of two semilunar segments, lying side by side. They occur much more frequently than in the veins, and as the wall of the lymphatic has a slight sinus or bulging opposite each valve, the vessel, when distended, has a beaded or moniliform appearance.

The *Lymph Capillaries* lie between the tissues of the organs in which they are situated. They are arranged in

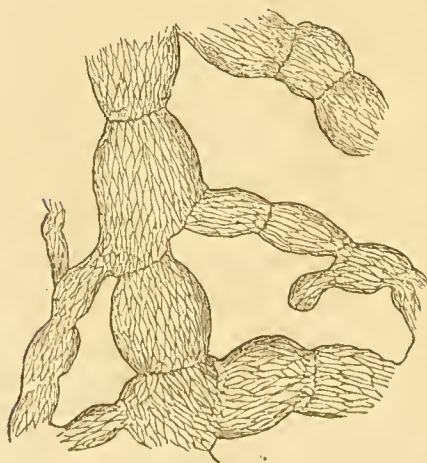


FIG. 144.—Lymph Capillaries and finer lymphatic vessels, from the lymphatic network beneath the peritoneal covering of the diaphragm. From a preparation made by Klein. $\times 80$ diam.

a network or plexiform manner, the meshes of which are polygonal. The capillary wall is formed of a single layer of elongated, flattened, endothelial cells, the outlines of which can be stained on the addition of a solution of nitrate of silver. The lymph capillaries, where they pass into the larger lymph-vessels, differ from the blood capil-

laries in possessing indications of a beaded or varicose appearance, due apparently to an imperfect valvular arrangement in the interior of the tube.

Origin of the Lymphatic Vessels.

The mode of origin of the lymphatic vessels is a difficult subject of study, and has long been a disputed question amongst anatomists. In the intestinal villi they are capillary tubes, which come apparently to a blind termination near the free end of the villus, though some observers have supposed that they are continuous with a minute network in the basis substance of the villus, and through it with the deeper ends of the epithelial cells covering the villus.

In the skin, the mucous and submucous tissues, the tendons, and other forms of connective tissue, lymph-capillaries form at their origin a compact polygonal network, which is apparently continuous with spaces in the connective tissue, situated either between its bundles or surrounding the connective tissue corpuscles. These spaces have been termed the *juice* or *plasma canals*; they are not vessels in the proper sense of the word, but, as it were, microscopic chinks in the tissue. They communicate freely with each other, and apparently with the lymph capillaries. It is an open question if these plasma passages possess any other boundary than that of the elements of the tissue in which they are situated, though some observers have described them as lined by a layer of endothelium. These plasma passages provide an arrangement by means of which the tissues can be permeated by a nutritive fluid derived from the liquor sanguinis, and afford room for the wandering colourless corpuscles which have migrated out of the blood-vessels. T. A. Carter has injected from the blood-vessels an extremely minute net-

work in the tissues, the strands of which are not more than $\frac{1}{4300}$ to $\frac{1}{8600}$ th of an inch in diameter; he names it the *diaplasmatic network*, and it is apparently the juice passages just referred to.

By Virchow and others it has been thought that the connective tissue corpuscles are continuous with the lymph capillaries, and these also have been named juice canals.

In some localities, as around the solitary and Peyer's glands, as well as around the glands of Brunner and other acinous glands, the lymph capillaries at their origin have not the form of cylindrical tubes, but are dilated into irregularly-shaped spaces, lined by an endothelium. Around the arteries of the pia mater, both external to and in the substance of the brain and spinal cord, are situated lymph-spaces, in the form of hollow cylinders, and termed the *peri-vascular canals*; and a similar arrangement has been seen around the small vessels at the border of the cornea.

In the sub-endothelial tissue of the serous membranes a close network of lymph capillaries is situated, which, as

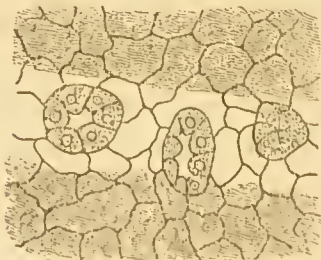


FIG. 145.—Endothelial cells from the peritoneal serous membrane. Three stomata may be seen surrounded by polyhedral nucleated cells; the one to the right is closed. The light band marks the position of a vertical lymphatic vessel. (After Klein.)

Recklinghausen pointed out, communicate with the serous cavity through small openings, or stomata, on its surface. These openings, as has already been described (p. 140), are surrounded by polygonal, distinctly nucleated cells, with granular contents, which differ in appearance from the ordinary

endothelial covering of the serous membrane. The serous

cavities have, therefore, been regarded as great lymph spaces freely communicating with the lymph-capillaries. But the fluid which the serous cavities contain is not lymph in the proper sense of the word, but a thin serum, in which a few lymph corpuscles may be suspended. In the view that the serous cavities are lymph spaces they may be regarded as affiliated to the lymph-lacunæ of the lower vertebrata. In the frog, for example, spaces exist in the subcutaneous region, which communicate with the lymphatic system, and in the same animal the aorta and other large arteries are enclosed in perivascular lymph spaces.

The thoracic duct and the right lymphatic duct are, as already described, the great channels of communication between the lymphatics and the veins, but other smaller connections have also been described in the human body. Wutzer saw in one subject two offshoots from the thoracic duct opening into the vena azygos. Nuhn has observed lymph-vessels opening into the renal veins and inferior cava; and Petrel has seen lymphatics communicating with the portal vein, renal veins, and vena azygos. It is possible that these smaller communications may enlarge and serve as important channels for the flow of lymph and chyle into the blood, in cases where the thoracic duct has become obliterated by pressure from an aneurism of the thoracic aorta.

It may be stated, that in amphibians, reptiles, and some birds, pulsating vesicles, with muscular walls, named *lymphatic hearts*, occur in connection with the termination of the lymph-vessels in the venous system, and, by their contraction, drive the lymph into the veins. No lymph hearts have, however, been found in the mammalia.

Two sets of capillary vessels occur in the tissues and organs, the blood capillaries and the lymph capillaries. The network of lymph capillaries is not continuous with or even in contact with the network of blood capillaries, but the lymph capillaries lie in the meshes of the blood capillary network, and are separated from them by intervening tissue elements. The blood which flows into the blood capillaries from the arterial system is for the most part conveyed directly onwards into the veins; but from the pressure to which the blood is subjected, in part

its liquor sanguinis, with perhaps some white corpuscles, transudes through the delicate coats of the capillaries into the tissues. That which is required for the nutrition of the tissue is applied to that purpose. That which is not needed would accumulate in the tissues, were it not that a drainage system is provided by means of the plasma channels, which convey it into the lymph capillaries, and from them it is transmitted into the larger lymph vessels. Hence, while



FIG. 146. —Diagram of the relation of the Blood and Lymph Capillaries amidst the tissues. A, small artery; bc, blood capillary network; lc, lymph capillary network; v, vein; L, lymphatic. The arrows indicate the course of the blood and of the lymph stream. The spaces between the capillaries of the two networks are occupied by the tissue of the part.

there is only one channel, viz., the arterial, for conveying pabulum to the tissues of an organ, there are two channels, viz., the venous and lymphatic, for conveying

the unemployed part of that pabulum back to the central part of the circulatory apparatus. Under some pathological conditions, the blood serum transudes in such quantities into the tissues that it cannot be conveyed away by the drainage system, so that it occasions an œdema, or a dropsical accumulation in the part.

LYMPHOID ORGANS.

In many parts of the body round, colourless cells, resembling the corpuscles of lymph, or the white corpuscles of the blood, are either infiltrated into the meshes of the connective tissue, or are collected into masses visible to the naked eye. These may appropriately be called Lymphoid Organs. Not unfrequently these organs are situated as node-like swellings in the course of the lymphatic vessels, and are invested by definite capsules, when they are known as *Lymphatic Glands*. At other times they are not separated from the surrounding connective tissue by a definite capsule, and apparently are not situated in the direct course of lymphatic vessels, though a network of lymph-capillaries may lie around them, when they are termed *Lymph Follicles*.

LYMPH FOLLICLES.

The Lymph Follicles are especially found in connection with the mucous lining of the alimentary canal, and occur in the mucous membrane of the back of the dorsum of the tongue, in the tonsils, the wall of the pharynx, as the solitary glands of the œsophagus, stomach, and intestines, and as the Peyer's glands in the small intestine: their characteristic tissue is also infiltrated into the basis substance of the intestinal villi, and into the connective tissue which separates the tubular intestinal glands from each other. But the lymph follicles are not confined to the alimentary mucous membrane. They are situated in the conjunctiva, where they form the trachoma glands, in the mucous membrane lining the Eustachian tubes, in the laryngeal, tracheal and bronchial mucous membrane, and they have also been seen in the mucous membrane of the urinary bladder and in that of the vagina. They are developed also in large numbers in the spleen, and form its Malpighian bodies. They constitute the structure of the thymus gland. Lymph follicles have also been described in relation to the pleura and the great omentum. The presence of lymph-follicles in the respiratory and intestinal mucous membranes is of interest in relation to the frequent formation of tubercle, under certain pathological conditions, in those localities.

The characteristic tissue of the lymph follicles has been variously named *lymphoid tissue*, *lymph-follicular tissue*, and *adenoid tissue*. It consists essentially of two structural elements: first, of colourless corpuscles resembling those of the lymph and blood; second, of stellate branch-

ing cells, the processes of which anastomose freely with each other, so as to form a network or reticulum of the retiform connective tissue (fig. 147). These cells are distinctly nucleated. This reticulum forms a sustentacular or supporting framework for the lymph corpuscles, which fill up the interstices of the mesh-work. When this lymphoid tissue is developed so abundantly in a locality as to form definite masses, or follicles, they usually possess a spheroidal or ovoid form, such as one sees in the solitary glands, in the individual glandules of a Peyer's patch, in the trachoma glands of the conjunctiva, the faucial and pharyngeal tonsils, and the Malpighian bodies of the spleen. At other times the tissue is not aggregated into masses, but is uniformly diffused throughout

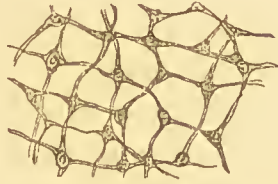


FIG. 147. — Retiform connective tissue from a lymphatic gland, $\times 300$.

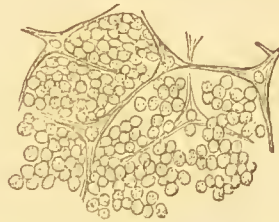


FIG. 148. — Lymphoid tissue, with the lymph cells situated in the interstices of the reticulum formed by the stellate retiform cells $\times 450$.

a particular locality, as is the case in the basis substance of the intestinal villi, in the interglandular connective tissue of the intestinal mucous membrane, and in the sheath and outer coat of the branches of the splenic artery. It not unfrequently happens, as in the tonsils and the conjunctival mucous membrane, that not only is the lymphoid tissue aggregated into definite masses or follicles, but that lymph corpuscles are infiltrated or diffused throughout the connective tissue, which surrounds the individual follicles.

The lymphoid tissue in the centre of a lymph follicle has a more open meshwork than at the periphery, where the retiform tissue is more compact and often simulates the appearance of an investing capsule. When a number of follicles lie close together, as in a Peyer's patch, the separate follicles may be connected together by intermediate retiform tissue.

The lymph follicles possess considerable vascularity. Not only do the blood-vessels form a network around the follicles, but, as may easily be seen in injected solitary and Peyer's glands, capillaries pass from the periphery to the centre of each follicle, and form in it a wide meshed plexus, the strands of which are in relation to the sustentacular framework.

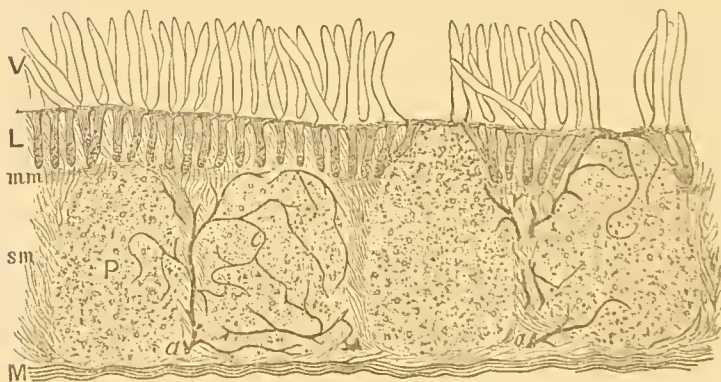


FIG. 149.—Vertical section through a Peyer's patch in the wall of the small intestine. V, the intestinal villi; L, the layer of Lieberkühn's glands; mm, the muscularis mucosae; sm, the connective tissue of the submucous coat; P, the follicles of a Peyer's patch. The two to the right are completely divided from the eupola to the base; the two to the left are cut through to one side of the apex; aa, small arteries in the submucous coat, which enter the follicles of Peyer, and form a capillary network; M, muscular coat. Slightly magnified.

Lymphatic vessels have a close relation to the lymph follicles. In the solitary and Peyer's glands of the intestine, where their arrangement has been chiefly studied, a network of lymph capillaries has been seen around the peri-

phery of the follicles. Frey has described the bases of these follicles as invested by a system of spaces or passages, continuous with and capable of being injected from the lymphatic system. It is possible that these spaces communicate with the meshwork of the retiform tissue of the follicle, but the communication has not been definitely ascertained. There can be no doubt, however, that the lymph follicles are appendages of the lymph-vascular system, and are the seats of production of lymph corpuscles. Nothing is known of the arrangement of the nerves in relation to the lymph-follicles.

Lymphatic Glands.

The Lymphatic Glands are nodal swellings occurring in the course of the lymphatic vessels. They are abundantly distributed throughout the body, and are found in clusters in the groin, axilla, neck, chest, abdomen, &c., as has been described in the section on the distribution of the lymphatic vessels. They often are arranged as a chain of glands connected together by intervening lymph vessels. They are round or oval in shape, and vary in size from a small shot to a kidney bean. It is not uncommon for the glands to enlarge and for adjacent glands to become fused together. Each gland receives at one end several lymphatic vessels called *vasa afferentia*, and from it lymphatic vessels, called *vasa efferentia*, emerge; which in their onward course may become afferent vessels for glands situated higher in the course of the lymphatic vessels (fig. 150). Where the efferent vessels pass out of a gland a depression on its surface, named the *hilus*, is often seen.

Each lymphatic gland is surrounded by a *capsule*, which

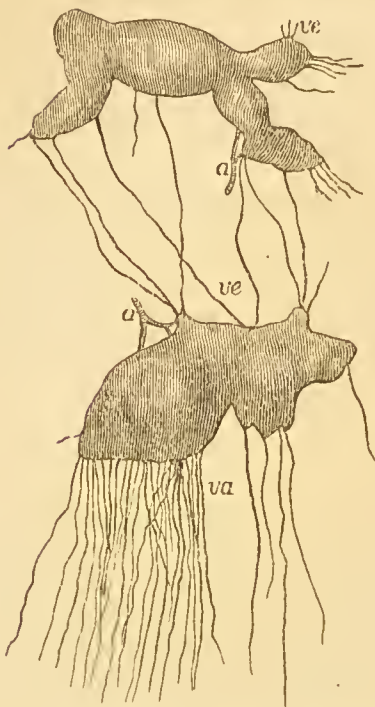


FIG. 150.—Cluster of Lymphatic Glands of the groin, between some of which fusion has taken place. *va*, vasa afferentia; *ve*, vasa efferentia; *a*, *a*, small arteries. Natural size

consists of interlacing bundles of connective tissue intermingled with non-striped muscular fibres, which in some animals, as the ox, are very numerous. When a section is made through a gland it is seen to consist of an external, yellowish-red, cortical part, and of a central, more deeply red, medullary part, which, however, reaches the surface at the hilus.

From the capsule thin laminæ pass into the *cortical* substance and form in it a trabecular framework,

which divides the cortex into a number of compartments or alveoli. These alveoli contain rounded nodules, consisting of the proper glandular or follicular tissue of the lymphatic gland, which is arranged therefore as a number of follicles, called the follicles of the cortex. As the trabeculæ do not form perfect partitions between adjacent follicles, the tissue of one follicle is to some extent continuous with that of those which lie around it. These follicles are formed of lymphoid tissue, resembling in structure the lymphoid follicles already

described, and the meshes of the reticulum are crowded with lymph corpuscles. Surrounding each of the follicles, and bounded by the trabeculæ, is a space traversed by a reticulum of the retiform connective tissue, the stellate



FIG. 151.—Semi-diagrammatic view of the structure of the cortex of a Lymphatic Gland. *c*, capsule; *t*, *t*, trabeculæ; *p*, lymph passage with retiform tissue; *f*, lymph follicle; *va*, vas afferens communicating with lymph passages; *a*, arteries and blood capillaries. Highly magnified.

cells of which are continuous on the one hand with the retiform tissue of the follicle, and on the other with the trabecular framework of the cortex. This space contains lymph corpuscles, which are easily washed out, and it obviously resembles the lymph spaces or passages which invest the bases of the follicles of a Peyer's patch. It communicates with the vasa afferentia, from which it can be injected. Owing to the continuity between the tissue of adjacent follicles, their surrounding lymph spaces are also continuous with each other, and form an anastomosing set of lymph passages within the cortex of the gland.

The *medullary* part of the lymphatic gland is also

traversed by a trabecular framework continuous with that of the cortex. The trabecles are arranged in a cylindriform manner, and enclose alveoli, which contain lymph follicles that possess a cylindrical form. Here also, as in the cortex, the lymphoid tissue of the follicles within adjacent



FIG. 152.—Semi-diagrammatic view of the medullary part and the hilus of a Lymphatic Gland. *hs*, stroma of hilus; *ve*, vas efferens; *a*, artery ending in capillaries; *c*, capsule; *tt*, trabeculæ; *pp*, lymph passage; *f*, follicles, highly magnified.

alveoli is continuous through gaps in the intervening trabecular wall. The medullary lymph follicles are surrounded by lymph passages, continuous, on the one hand, with the lymph passages in the cortical part of the gland, and on the other, with the vasa efferentia, with which the medullary substance comes into direct relation at the hilus. The medullary lymph passages can be injected from the vasa efferentia. The surfaces of the trabeculæ which bound the lymph passages both in the cortex and medulla are covered by a layer of endothelial cells con-

tinuous with the endothelium of the vasa afferentia and efferentia.

Through the researches of His, Frey, and Recklinghausen, it has now therefore been established that a lymphatic gland is permeated by an anastomosing system of lymph passages or channels, continuous with the afferent and efferent vessels. These channels surround the follicular masses of lymphoid tissue, and as the stream of lymph flows through the gland, it washes lymph corpuscles out of the meshes of this lymphoid tissue, which corpuscles mingle with the lymph stream and are carried onwards in its flow. The lymphatic glands are the seats of production of lymph corpuscles, and are the great centres of origin therefore of the white corpuscles of the blood.

Each lymphatic gland receives at least one small artery, which enters at the hilus, and breaks up into branches that in part ramify in the capsule and trabecular framework, and in part pass directly to the follicular tissue. Capillaries are distributed in the follicular tissue in which they form a plexus; they supply the pabulum for the nutrition and production of the lymph corpuscles: veins arise from this plexus and pass out of the gland at the hilus.

In many lymphatic glands a quantity of fibrous connective tissue, named by His the *hilus-stroma*, is situated at the hilus, and surrounds the artery, vein, and vasa efferentia. It also not unfrequently contains a collection of fat cells. Vaso-motor nerves accompany the blood-vessels into the gland, and supply not only their muscular coat, but the muscular tissue of the capsule and trabeculae. Nerve-cells have also been described on these nerves by some observers.

THE DUCTLESS GLANDS.

In several parts of the body soft, vascular, glandular-looking organs are found, which differ from secreting glands in not possessing an excretory duct, and, in consequence of this anatomical character, have long been known as the DUCTLESS GLANDS, or GLANDS WITHOUT DUCTS. The spleen, thyroid gland, thymus gland, supra-renal capsules, pineal gland, and pituitary body are all distinguished by this peculiarity. From recent observations on their structure and functions, it has been ascertained that some of the ductless glands have a physiological relation to the blood-vascular system, and they have consequently been called the BLOOD-VASCULAR GLANDS. As two of these glands, viz., the spleen and thymus, contain large quantities of lymphoid tissue, and are the seats of production of lymph corpuscles, they have been named BLOOD-LYMPH-VASCULAR GLANDS. It is possible that the thyroid gland, the pituitary and pineal glands, and the supra-renal capsules, may have a physiological relation to the vascular system, but as their structure differs in some particulars both from each other, and also from that of the spleen and thymus, their exact function is even yet involved in much obscurity. It may also be stated, that by some observers the coccygeal and intercarotic bodies have been referred to the blood-vascular glands, but their structure more closely approaches that of a modified rete mirabile. I have preferred, therefore, to group these glands together by the term Ductless Glands, which expresses an anatomical character common to the whole series, rather than to employ the term Blood-Vascular Glands, used by many writers,

which implies that all these organs possess a special relation to the blood-vascular system.

THE SPLEEN.

The Spleen is the largest of the ductless glands. It lies in the costal zone of the abdomen, and is so deeply placed in the left hypochondrium that, when the abdomen is opened, it is not seen until the stomach is drawn on one

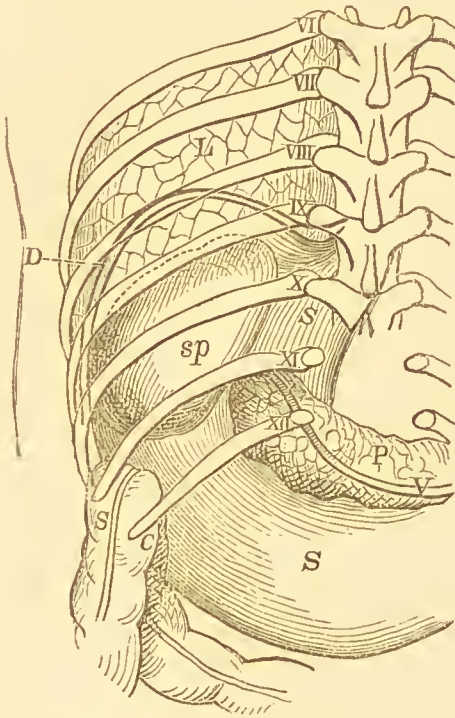


FIG. 153.—View of the Spleen and Stomach from behind, after the removal of the intercostal and lumbar muscles. VII to XII, the lower seven ribs; L, the lung; SS, stomach; *sp*, spleen; P, pancreas; V, splenic vein; SC, splenic flexure of colon; D, diaphragm; the black line immediately below which is the fundus of the stomach. Modified from Luschka.

side, for it is situated between the diaphragm and the posterior surface of the stomach. It lies obliquely from

above downwards and forwards, and as Luschka has pointed out, is in front of and follows the curvature of the ninth, tenth, and eleventh ribs. Its inner and upper end, when the spleen is of average size, is about 1 inch from the spinal column, its outer and lower end reaches to about $1\frac{1}{2}$ inch from the tip of the eleventh rib. It varies much in size in different individuals, and at different times in the same person, but its average length is from 5 to 6 inches, and its breadth from 3 to 4 inches, whilst its weight varies from 5 to 7 ounces.

The spleen is elongated in shape, and possesses two surfaces, two borders, and two extremities. The *outer surface* is smooth and convex, and in close contact with the concave under surface of the left half of the diaphragm; the movements of which muscle it follows during inspiration and expiration. The *inner surface* is concave, and in relation to the back of the stomach, to which it is attached by a fold of peritoneum, the *gastro-splenic omentum*. This surface is marked by several depressions through which the blood-vessels, lymphatics, and nerves enter the substance of the spleen; these depressions collectively constitute the hilus. The left supra-renal capsule and kidney are in relation to a small part of this surface, situated behind the attachment of the gastro-splenic omentum. The *anterior border* often presents a notched or crenulated appearance. The *posterior border* is thicker and more rounded than the anterior. The *upper and inner extremity* is attached to the diaphragm by a fold of the peritoneum, named the *suspensory or phrenico-splenic ligament*. The *lower and outer end*, more pointed than the upper and inner end, is in relation to the splenic flexure of the colon and the phrenico-colic ligament.

The great increase which not unfrequently takes place in the bulk of the spleen, leads to an extension of its relations to surrounding parts; and in these cases it may be seen appearing at the side of the great curvature of the stomach, or even projecting, obliquely downwards and forwards, into the lumbar or umbilical regions of the abdomen. Occasionally also portions of spleen substance are detached, and form *accessory spleens*, situated in the great omentum, or in the gastro-splenic omentum. More rarely the spleen is divided into a number of perfectly distinct lobes; a condition which is normally found in some animals, as the pilot whale.

Structure.—The spleen is a solid organ of a bluish-purple colour, and so soft in its texture that it is easily ruptured and torn. It possesses two coats,—a serous and a fibrous.

The *serous* or *external coat* is a part of the peritoneal membrane. It invests the spleen, and is reflected from it to the diaphragm as the suspensory ligament, and to the stomach as the gastro-splenic omentum.

The *fibrous coat*, or *tunica propria*, is immediately subjacent and intimately united to the serous coat. It is composed of white fibrous tissue with elastic fibres; in many animals, as the ox and dog, it contains a large proportion of non-striped muscular tissue, but in man the muscularity is only feeble. At the hilus it passes into the interior of the spleen along with the vessels and nerves, for which it forms sheaths. From the whole extent of the inner surface of the tunica propria processes pass into the substance of the spleen, which interlace freely with each other so as to form a network, the *trabecular framework* of the spleen. The individual beams, or

trabecles of this framework, possess a similar fibro-elastic and muscular structure to that of the fibrous coat. The blood-vessels ramify in the interior of the spleen in close relation to the trabecles. The intervals between the trabecles are irregular in form and size, and are occupied by a soft reddish substance, the *spleen pulp*. If a section be made through the spleen, and a current of water be directed on the surface of the section, the spleen pulp is easily washed out of these intervals, and the trabecular framework is left.

The examination of the more minute structure of the spleen is attended with many difficulties, more especially

as regards the mode of termination of the splenic artery, the commencement of the vein, and the relation of the splenic blood-vessels to the spleen pulp. When the pulp is examined microscopically, it is seen to contain fine blood-vessels, spheroidal bodies called the Malpighian corpuscles, numerous cells, and a delicate reticulum of connective tissue. By one set of observers, as W. Müller and Frey, it is believed that the blood in passing from the

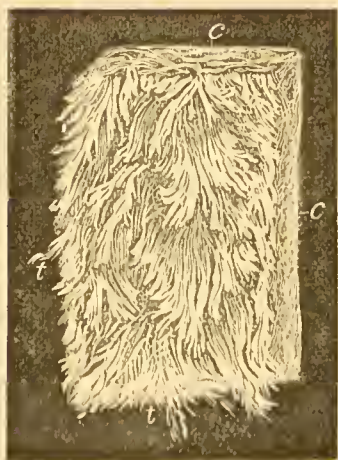


FIG. 154 —The trabecular framework *t, t*, of the Spleen after the spleen pulp has been washed out; *c, c*, the fibrous coat seen in section. Natural size.

splenic artery into the splenic vein flows into channels, which have no continuous tubular walls, so that it comes

into direct relation with the cells and reticulum of the spleen pulp. By other observers again, as Billroth and Kölliker, it is held that the continuity of the vascular wall from the splenic artery to the splenic vein is preserved, and that the reticulum and pulp-cells lie outside the wall of the blood-vessels.

The following description, though agreeing in its main features with the descriptions of W. Müller and Frey, is chiefly based on my own observations on the structure of the human spleen and that of the rat.

The reticulum of the spleen pulp has been named the *intervascular network*: it is situated in the intervals between the trabecles, and consists of a retiform connective tissue, such as makes up the framework of a lymph follicle. The strands of this framework are composed of stellate and nucleated connective tissue cells, the processes of which anastomose with each other, but fusiform cells are intermingled with them. The interstices between these stellate cells are occupied by lymphoid and other colourless corpuscles, and by red blood corpuscles, and intervene between the capillary terminations of the arteries and the commencement of the veins, so that they are channels for the blood to flow through. They constitute a special modification of the circulatory apparatus, and are a sort of cavernous rete mirabile, not enclosed within an endothelial wall, and the stellate cells themselves form a supporting frame-



FIG. 155.—Cells of the pulp of the human Spleen. *s*, the stellate retiform cells; *ps*, colourless corpuscles of the spleen pulp. $\times 450$.

work for the blood-corpuscles and the lymphoid corpuscles of the spleen pulp. The colourless lymphoid corpuscles have distinct nuclei, relatively large to the size of the cells, and with them are a few cells, also with distinct nuclei, but with a larger proportion of protoplasm, and somewhat polygonal in shape. In addition to the red blood corpuscles possessing the normal appearance, shrivelled red corpuscles and pigment granules are also seen, together with large cells containing several red corpuscles or pigment granules. Frey supposes that these large cells are colourless corpuscles, which have taken into their interior either entire red corpuscles, or portions of their substance, which present the appearance of clumps of yellow pigment. Owing to the elasticity of the fibrous coat and trabecles of the spleen, and the free communication of the blood-vessels with these interstices, they at times become engorged with blood: if the splenic artery be artificially injected, they are easily distended by the injection.

The splenic artery is the largest branch of the cœliac axis, and is large in relation to the size of the spleen. It divides into five or six branches before entering the hilus. After it has passed into the spleen it continues to divide and subdivide, branching dichotomously, without any anastomoses between its branches. When traced down to its finest ramifications it breaks up into clusters of branches or *penicilli*, which are usually compared in their arrangement to the hairs of a paint brush, though Frey regards them as more like the branches of a willow tree deprived of its leaves. The branches of the artery are enclosed in a sheath continuous at the hilus with the

fibrous coat of the spleen. An important metamorphosis takes place in the structure both of the sheath, and of the tunica adventitia of the smaller branches of the artery, which lose their fibro-elastic character, and become transformed into lymphoid tissue.



FIG. 156.—Vertical section through the Spleen to show the Malpighian corpuscles. *c*, the fibro-muscular coat; *t, t*, trabeculae; *M, M, M*, Malpighian corpuscles; *A, A, A*, arteries of the spleen; *p*, penicilli; *sp, sp*, spleen pulp. $\times 80$.

In many localities this lymphoid tissue increases so much in amount, as to form minutespheroidal or elliptical bodies—the *spleen-follicles*—just visible to the naked eye, and long known as the *Malpighian bodies* or *corpuscles*. Each of these bodies is therefore developed in relation to the wall of an artery. When the development takes place around the entire circumference of the wall, the Malpighian body is penetrated by the artery, which seems to form therefore its peduncle or stalk; the passage of the minute arteries into and through the Malpighian bodies was first pointed out by W. R. Sanders; when the formation of the Malpighian body is limited to one aspect only of the wall of the artery, then it is sessile on the vessel. At one time it was thought that each Malpighian

body possessed a definite capsule which separated it from the surrounding spleen pulp, but it is now known that the appearance of a capsule is due to only a greater density of the peripheral layers of the lymphoid tissue, of which the Malpighian body is composed. The meshes of the lymphoid tissue of the Malpighian body are infiltrated with colourless lymph cells. Busk and Huxley showed that the retiform tissue which forms the supporting framework of these lymph cells is continuous with the retiform tissue of the pulp. Capillaries are distributed within the Malpighian bodies, which may arise either from the arteries that penetrate them, or may enter them from without.

The capillary terminations of the finest branches of the splenic artery, both in the Malpighian bodies and in the surrounding spleen pulp, do not end directly in veins, but, according to W. Müller and Frey, open into the interstices of the intervacular network already described. The wall of the capillary, it is said, loses its tubular form, and its endothelium becomes continuous with the stellate cells of the retiform connective tissue of the pulp. Schweigger-Seidel and W. Müller state, that whilst some of the capillaries possess simple walls, others have distinct sheaths, consisting of a delicate connective tissue with round or elongated nuclei, and Frey has pointed out, that as this sheath approaches the arterioles, it assumes the characters of lymphoid tissue.

If the splenic artery be carefully injected, the injection passes out of the capillaries, and forms an anastomosing stellate network, situated between the colourless corpuscles of the spleen pulp. At first sight it appears as if the

stellate corpuscles of the reticulum had been filled with injection, so closely does the injected network resemble in form the intervacular network of stellate cells (fig. 155); but it is more probable that the reticulum merely guides the course of the injection, which lies outside the stellate cells, and not within them (fig. 157). The injected stellate network is well marked in the peripheral part of the Malpighian bodies, and is continued into their interior, so that the network within the Malpighian body is continuous with that in the surrounding spleen pulp.

The veins of the spleen do not arise directly from capillaries, but from the interstices of the intervacular network. The venous radicles are arranged as a close plexus, and possess simple walls, formed apparently of only a single layer of fusiform endothelial cells, so that they were named by Billroth *capillary veins*. Where they come into relation with the intervacular network, it is said that the continuity of their walls is interrupted, their endothelial cells are separated from each other, and assume the character of the retiform connective tissue, and their lumen communicates with the interstices of that network.



FIG. 157.--The injected stellate network in the human Spleen pulp. *c*, an injected capillary; *n*, the injected intervacular stellate network tinted grey in the figure; *s*, stellate cells; *ps*, the lymphoid corpuscles of the spleen pulp. $\times 450$.

From the plexus of capillary veins the proper tubular veins arise, which join together to form larger trunks,

that leave the spleen at the hilus, along with the branches of the splenic artery. It seems now to have been established that the blood of the splenic artery flows into capillaries; but before it enters the veins, it has to traverse the interstices of the intervacular network of the spleen pulp, in which interstices quantities of lymphoid cells are situated, which cells are washed into the blood stream, and are conveyed into the splenic vein; so that the spleen pulp serves as a centre for the production of white blood corpuscles, and the blood of the splenic vein contains a larger proportion of white blood corpuscles than that of the splenic artery. The spleen, therefore, may be compared with a lymphatic gland, but with this difference, that while in the latter the stream which flows through the organ and collects the lymph corpuscles is lymph, in the former organ it is blood.

The lymphatics of the spleen form a superficial and a deep set. The superficial lymphatics were injected by Alex. Monro, *secundus*, and form in the ox's spleen a network of large vessels with distinct valves. Deep lymphatics, continuous with the superficial set, ramify in the trabecular framework. According to Tomsa, deep lymphatics accompany the arteries, and probably form networks around the Malpighian corpuscles. It has also been surmised that they arise from the lymphoid tissue in the coat of the smaller arteries.

Nerves from the solar plexus accompany the splenic artery and its branches throughout the substance of the spleen. Ganglion cells have been described on these nerves.

THYMUS GLAND.

The Thymus Gland is found in all animals which breathe by lungs, though it has no physiological connection with them. It is a fawn-coloured, lobulated body, situated in the upper part of the thorax, and in the lower part of the neck of infants and children. It lies for the most part in the anterior mediastinum, but is prolonged upwards into the neck in close relation to the trachea as far as the lateral lobes of the thyroid body. Its thoracic part is immediately behind the sternum, and in front of the pericardium, the left innominate vein, the aortic arch, and its three large branches. The thymus consists of two lateral lobes, somewhat triangular in form, but of unequal size. The broader part of each lobe lies in the thorax, and the narrower end forms the cervical prolongation. The two lobes are closely attached to each other by intermediate connective tissue, so that at first sight they seem to constitute a single organ. The gland reaches its maximum size about the end of the second year; after which it remains stationary for some years. About the eighth year it begins to undergo fatty degeneration, and at the time of puberty it forms two elongated lobes of fatty tissue, situated in the anterior mediastinum, in which condition it is found during the rest of life. In rare cases the thymus may retain its proper structure until after puberty; I have seen it in the adult hartebeest and nylghau preserving its normal structure.

Structure.—Each lobe of the thymus gland is invested by a capsule of connective tissue, which is prolonged into the substance of the lobe and divides it into *lobules*.

The lobules are arranged as if grouped around an axis spirally twisted stem, in which the vascular trunks of the gland are situated. By some observers the stem is believed to be hollowed out into a *central canal*. The lobules are still further subdivided into numerous *thymus follicles*. Each thymus follicle is formed of lymphoid tissue corresponding in structure to the lymph follicles already described (p. 547). The thymus follicles may either be separated from each other by distinct capsules; or the infiltration of lymph corpuscles into the meshes of the connective tissue may be so great that adjacent follicles appear to have run together. Bodies presenting a concentric appearance, the *concentric corpuscles* of Hassall, also occur, and, in the later stages of growth, cells containing oil drops, which mark the commencing fatty degeneration of the gland, are also present. The lobules of the thymus frequently contain a space in the centre, which some observers regard as normally present, though others consider it to be produced artificially by the breaking down of the lymphoid tissue of the centre of the lobule.

The thymus gland receives its supply of blood from the thymic branches of the internal mammary, and from the superior and inferior thyroid arterics. They pass to the stem of each lobe, and send off lateral branches to the lobules, which end in a capillary network within the thymus follicles. The veins which arise from the capillaries, pass out of the lobes to end in the internal mammary and innominate veins.

Lymphatics are situated in the connective tissue between the lobules and follicles, but their relation to the lymphoid

tissue of the follicles has not been traced. They leave the thymus along with the blood-vessels, and join the lymphatic glands in the anterior mediastinum. Fine nerves pass to the thymus along with the arteries, and offsets of the cardiac plexus are said to enter it.

The lymphoid tissue of the thymus gland may serve as the centre of production of the large lymphoid intra-thoracic tumours, sometimes developed in the anterior mediastinum.

THYROID GLAND.

The Thyroid Gland, or Thyroid Body, is a very vascular organ, of a reddish-brown colour, situated in the anterior part of the neck, in close relation to the sides and front of the windpipe. It consists of two lateral lobes united together by an intermediate median lobe or isthmus. Each *lateral lobe* is about two inches long, one inch wide, and three-quarters of an inch in thickness. The lateral lobe lies in close relation to the side of the thyroid and cricoid cartilages, and extends as far down as the fifth or sixth ring of the trachea; and it is connected to the laryngeal and tracheal cartilages by areolar tissue. The *median lobe* or *isthmus* varies in its vertical diameter from $\frac{1}{4}$ to $\frac{3}{4}$ inch; it passes transversely across the front of the trachea opposite its third and fourth rings, and connects together the lower ends of the two lateral lobes.

The thyroid gland is covered by the sterno-hyoid, sterno-thyroid, and omo-hyoid muscles, and its posterior border comes into relation with the common carotid artery.

Occasionally, though Luschka says in every third

person, a prolongation of the gland, named the *pyramid*, ascends from the upper border of the isthmus, in front of the cricoid and thyroid cartilages, as far even as the hyoid bone. A muscle, called *levator glandulæ thyroideæ*, is often seen passing from the pyramid, or the adjacent part of the gland, to the hyoid bone. The gland is normally bigger in women than in men. It often undergoes a pathological enlargement, named bronchocele or goitre. In many mammals, as the camel, alpaca, nyghau, hartebeest, dog, warthog, porcupine, and kangaroo, the isthmus is wanting, and the two lateral lobes are quite disconnected; whilst in the feline carnivora the isthmus is very small in relation to the size of the lateral lobes.

Structure.—The thyroid gland is closely invested by a thin capsule of connective tissue, and is not divided into definite lobules, capable of separation from each other. When sections are made into its substance it is seen to be made up of numbers of closed vesicles, separated from each other by intermediate connective tissue, which is continuous with the investing capsule. These vesicles are just visible to the naked eye, and are spherical or ovoid in form (fig. 158). Each vesicle is said to be bounded by a delicate hyaloid membrane, lined on its inner surface by a single layer of somewhat cubical epithelial cells; but Peremeschko thinks that no hyaloid membrane is present, and that the cells rest directly on the surrounding connective tissue. The vesicles contain a translucent, viscous fluid, which coagulates by the action of heat, alcohol, or nitric acid. The enlargement of the gland in goitre is due to a distension of the vesicles, and an accumulation of the glairy colloid fluid in their interior.

The thyroid gland is abundantly supplied with blood by the superior and inferior thyroid arteries, which freely anastomose with each other in its substance. Occasionally an additional artery, the *arteria thyroidea ima*, a branch of the innominate artery, ascends to the thyroid gland in front of the trachea. The capillaries, in which the arteries terminate, form a compact polygonal network in the connective tissue immediately surrounding the closed vesicles. The veins which proceed from the capillary network form plexuses at the surface of the gland, and give rise to the superior, middle, and inferior thyroid veins. Lymph-vessels arise in the connective tissue between the closed vesicles and by anastomosis form larger vessels,

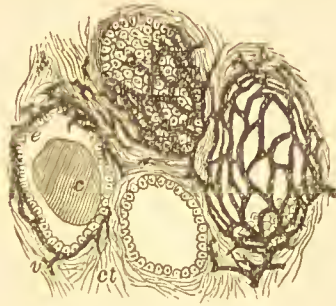


FIG. 158. Section through the injected Thyroid gland of a lion, to show the gland vesicles and the intervesicular connective tissue. *e*, the epithelial lining of a vesicle; *v*, the blood capillary vessels surrounding the vesicles; *c*, colloid mass in one of the vesicles.

which leave the gland at its surface, where they form a dense network. The nerves form a superior and an inferior thyroid plexus, which accompany the corresponding arteries. They arise from the middle and inferior cervical ganglia of the sympathetic, and have nerve cells interspersed in their course.

SUPRA-RENAL CAPSULES.

The Supra-renal Capsules or Glands, or Adrenals, are two bodies situated in the cavity of the abdomen, one in relation to the upper end of each kidney. Each gland lies at about the level of the twelfth dorsal vertebra, and is in contact with the fleshy part of the crus of the diaphragm by its posterior surface. In front of the right gland is the liver; in front of the left gland are the pancreas and spleen. Each gland has been compared in shape to a cocked hat, and the lower concave surface fits on the upper end of the kidney, to which it is attached by areolar tissue. A fissure, named the *hilus*, which transmits the supra-renal vein, exists in the anterior surface. Each gland measures on the average about $1\frac{1}{2}$ inch in its vertical diameter, 1 inch in its transverse, and $\frac{1}{4}$ inch in thickness. Relatively to the size of the entire body, these glands are somewhat larger in new-born children than in adults.

Structure.—The supra-renal gland is invested by a thin capsule of connective tissue; it sends processes into the interior of the gland, which form a trabecular arrangement, in the meshes of which cells are situated. If the gland be cut across, it is seen to be divided into an external, firm cortical part, of a yellow colour; and a central, soft, medullary part, of a deep brown colour.

The *cortical* part consists of cells imbedded in a trabecular framework of connective tissue, and is described by Julius Arnold as if arranged in three zones. The outer layer, or *zona glomerulosa*, is thin, and its connective tissue surrounds roundish spaces or alveoli, occupied by

groups of roundish or ovoid nucleated cells. The middle layer, or *zona fasciculata*, is relatively thick, and its connective tissue is arranged in longitudinal meshes, perpendicular to the surface of the gland; the spaces or alveoli of the meshwork are elongated, and occupied by groups of polyhedral cells, arranged in parallel columns, so that this layer presents a striated appearance. The inner layer, or *zona reticularis*, is thin, and its connective tissue forms a small meshed network occupied by groups of polyhedral cells. The cells of the several layers of the cortex are distinctly nucleated; the protoplasm is coarsely granular, and in those of the inner layer contains pigment granules; sometimes delicate protoplasm processes jut out from the periphery of the cells. In all the layers the spaces of the meshwork, occupied by the groups of cells, are traversed by a very fine reticulum of connective tissue, which separates the individual cells in each group from each other.

The *medullary* part is so soft as to be easily broken down. It is separated from the cortical part by connective tissue, and is traversed by a trabecular stroma of connective tissue, which forms a network, in the meshes of which the medulla cells are lodged. These cells are polyhedral in form, with a clear nucleus, and finely granular protoplasm, free from fat and pigment. Delicate processes not unfrequently jut out from the periphery of the cells, and give them a stellate form. Henle showed that they are stained deep brown by chromic acid, or bichromate of potash, which is not the case with the cortical cells.

The supra-renal glands are supplied with blood by the capsular branches of the aorta, and by the capsular branches of the phrenic and renal arteries. They pierce

the investing capsule, and end in a capillary plexus, which is distributed in the trabecular framework of connective tissue ; and the meshes of the capillary plexus correspond in their general arrangement with that of the connective tissue in which they ramify. Arnold states that they form glomeruli in the zona glomerulosa, elongated meshes in the zona fasciculata, and a fine network in the zona reticularis and in the medulla. In the medullary part the large capsular vein arises, and smaller veins spring from the capillaries of the cortical part. Lymph vessels have been seen to leave the supra-renal glands, but their distribution in them is not known. Nerves are very abundantly distributed to the gland : they are derived from the renal, capsular, and phrenic plexuses of the sympathetic, and from the phrenic and pneumogastric nerves ; so abundant are they, indeed, that Bergmann and Luschka consider the glands to be more intimately associated with the nervous system than with any of the other organic systems. They traverse both the cortical and medullary parts of the organ, and have nerve cells associated with them. Small detached accessory supra-renal glands are sometimes seen.

The function of the supra-renal glands is not fully ascertained. A curious correlation between pathological changes in these bodies and a bronzed hue of the skin, accompanied by emaciation and debility, has been pointed out by Addison.

PITUITARY GLAND.

The Pituitary Gland, or Hypophysis cerebri, is a small body, about the size of a pea, situated in the pituitary fossa in the upper surface of the body of the sphenoid bone. It is attached to the base of the brain by the funnel-shaped process, or *infundibulum*. It is divided into two lobes, an anterior and a posterior. The anterior is the larger, is invested by a capsule, and is divided by a framework of connective tissue into a number of small alveoli, which are occupied by groups of polygonal cells arranged in the form of columns. Blood-vessels pass into the connective tissue framework, in which is found a capillary plexus. The posterior lobe possesses a framework of connective tissue, intermingled with varicose nerve fibres, and small cells, some of which are polygonal, others fusiform. A plexus of capillaries lies in its connective tissue stroma. The anterior lobe corresponds in its type of structure with the supra-renal capsules, whilst the posterior lobe is an appendage of the brain.

The pituitary body is larger in proportion in the foetus than in the adult, and the cavity of the third ventricle is prolonged into it through the infundibulum. Though its function has not been ascertained, it is found throughout the vertebrata at the base of the brain.

PINEAL GLAND.

The Pineal Gland, Conarium, or Epiphysis cerebri, is a reddish body, shaped somewhat like a minute fir cone, which is enclosed within the velum interpositum of the pia mater. It lies on the anterior pair of the corpora quadrigemina of the cerebrum, under cover of the posterior end of the corpus callosum. Attached to its anterior surface are two white bands of nerve fibres, which pass forwards on the inner sides of the optic thalami, and are named the peduncles of the pineal gland. It is invested by a capsule, and is divided by an internal framework of connective tissue into small alveoli, which contain roundish lymphoid cells, spindle-shaped cells, and multipolar cells. The stroma contains a network of capillary blood-vessels and medullated nerve fibres. The multipolar cells are larger than the lymphoid and spindle-like cells, and are believed by some observers to be nervous. It is often hollowed out into one or two cavities, which contain not only an inspissated fluid, but amylaceous and gritty calcareous particles, termed brain sand. It is developed in relation to the upper part of the third ventricle, and is present throughout the vertebrata. Its function is unknown.

DEVELOPMENT OF THE VASCULAR SYSTEM.

The vascular system is formed in the middle or mesoblast layer of the germinal membrane of the early embryo.

The *Blood-vessels* first appear in that part of the mesoblast which forms the vascular area. The cells of the mesoblast lose their original spherical form and become stellate, the processes of adjacent cells unite together and form a network, and the nuclei rapidly increase in numbers. The peripheral part of the protoplasm of the stellate cells differentiates into a wall of nucleated protoplasm, and forms the wall of the primary embryonic blood-vessel, the central part of the protoplasm liquefies and forms vacuoles in the cells, and the nuclei in this liquefied protoplasm become the blood-corpuscles. If the vessel remains as a capillary, its wall assumes merely the character of a single layer of endothelial cells. If it becomes an artery or a vein, the mesoblast cells, lying immediately external to the primary blood-tube, apply themselves to the exterior of its wall, and differentiate into the muscular and elastic coats and the tunica adventitia. A similar mode of development of the blood-vessels apparently takes place within the body of the embryo itself. The formation of blood-vessels in the healing of wounds, and in some pathological processes, is also from the cells of the part in which the blood-vessels arise.

The *Lymph-vessels* also arise in a manner closely resembling the origin of blood vessels. The cells of the part branch and anastomose with each other. According to Klein, vacuoles appear in these cells, so as to form a cavity, and the vacuoles of adjacent cells in time communicate with each other, and form an anastomosing series of lymph capillaries. The nucleated protoplasmic wall of the cells forms the nucleated endothelial wall of the capillaries, and from this wall portions of the protoplasm may separate off into the lymph-tube and form lymph corpuscles.

The *Heart* begins to form in the body of the early embryo at the same time that the blood-vessels appear in the vascular area. It is placed at the cephalic end of the embryo, close to the cephalic fold of the amnion, and arises in the splanchnopleure layer of the mesoblast. It is at first attached to the primitive pharynx by a delicate membranous fold. It has been customary to regard it as developed out of a solid mass of cells, the central part of which mass liquefies to form blood and blood corpuscles, whilst the peripheral

cells arrange themselves so as to form the wall of a single tube. The cells of the wall are contractile, and in the course of time differentiate into muscular tissue and an endocardium. But from the recent observations of Kölliker, on the early stages of development of the mammalian embryo, it would appear that the single tube is preceded by a stage, in which there are two tubes situated side by side, which, however, soon fuse together and then form a single tube. This tube receives at its posterior end two *omphalo-mesenteric veins* from the vascular area. It gives off anteriorly two arteries, the *ventral aortic roots*, which run forwards at the sides of the primitive pharynx; they then arch towards the embryonic spine, run backwards below the primordial vertebræ, and form the two *primitive dorsal aortæ*, from which arise the omphalo-mesenteric arteries that pass into the vascular area. Two transverse constrictions then appear in the wall of the simple heart tube, which indicate a differentiation into three chambers—a posterior or *primitive auricle*; an anterior, the arterial bulb or *truncus communis arteriosus*; and an intermediate chamber or *primitive ventricle*. At the same time, a sigmoid bend takes place in the tube, which becomes doubled on itself, so as to throw the primitive auricle on the dorsal surface of the primitive ventricle. This condition of the heart in the human embryo is found at about the third week of development, and it represents the permanent condition of the organ in fish. A few cases have been recorded in which the development of the human heart had not passed beyond this stage, and the child was born with only a single auricle and a single ventricle.

Changes then begin to take place in the interior of the three chambers into which the tube has become divided, which result in the conversion of the single auricle into two auricles, of the single ventricle into two ventricles, and of the truncus communis arteriosus into the ascending aorta, and the trunk of the pulmonary artery.

The conversion of the *primitive ventricle* into two ventricles is due to the formation of a muscular septum in the ventricular chamber. It appears at about the sixth week in the human heart, and grows from the apex to the base of the ventricle. The apex of the ventricle then becomes the apex of the heart, and a groove, on the anterior and posterior surfaces of the ventricular part of the heart, marks the position of the two borders of the septum. The base of the septum, and the bases of the ventricles, are directed to the auricles and the orifices of the great arteries. The septum is complete about the eighth week, and the two ventricles then form

two distinct chambers. In rare cases the development of the septum stops short before its base is finished, and then the two ventricles have a permanent direct communication with each other. This malformation of the human heart corresponds with the normal construction of the heart in the Chelonia and Scaly Reptiles.

The *primitive auricle* is larger in size than the primitive ventricle, and, before its division takes place, two pouch-like projections, the right and left auricular appendages, appear on its walls. The conversion of the primitive auricle into two auricles is due to the formation of a septum in the auricular chamber. This septum appears about the eighth or ninth week, and not until the ventricular septum is completed. It springs as a muscular septum from the anterior and upper wall of the auricle and the base of the ventricular septum, and grows into the auricular chamber, in the direction of the mouths of the great veins. About the end of the sixth month the septum has grown so much that the anterior parts of the two auricles are separated from each other, but they freely communicate posteriorly, and the great veins open therefore into the common cavity. These veins are now three in number, and constitute the inferior vena cava, the right superior cava, and the left superior cava, the last of which subsequently becomes modified into the coronary sinns. A crescentic membranous fold, which grows towards the upper and lower boundaries of the auricle, then arises from the left wall of the inferior cava. At the same time it projects into the auricular chamber, and approximates to the muscular part of the septum, but between the two a hiatus, called the *foramen ovale*, exists, during the whole of intra-uterine life. With the growth of the membranous part of the septum, the orifice of the inferior vena cava, which at first opened towards the left half of the auricular chamber, is directed into the right auricle; but up to the birth of the child the blood of the inferior cava flows through the foramen ovale into the left auricle. Some days after the child is born, the number of which varies in different instances, the foramen ovale closes up by the union of the anterior and posterior parts of the auricular septum, and the two auricles are then completely separated from each other. In some cases the closure of the foramen is not complete, and a small valvular opening remains in the septum throughout life; more rarely the opening is large, and allows of a mixture of the blood of the two sides of the heart. From the right wall of the inferior cava, a membranous fold, the *Eustachian valve*, arises, which grows to the border of the anterior part of the auricular septum, where it forms the *annulus ovalis*, or

anterior boundary of the foramen ovale. It directs the blood of the inferior cava through this foramen into the left auricle.

The auriculo-ventricular valve arises around the aperture of communication between the auricle and ventricle as a semilunar fold of the endocardium. These folds then become connected with the muscular trabeculæ of the ventricular walls, which differentiate into the muscoli papillares, whilst the chordæ tendinæ are produced by the depending border of the valve assuming a fenestrated appearance.

The conversion of the *truncus communis arteriosus* into the ascending aorta, and the trunk of the pulmonary artery, is due to the formation of a longitudinal septum in the single arterial trunk. This septum begins to form about the same time as the ventricular septum, and consists of two folds projecting one from each side of the inner surface of the common arterial trunk. These folds meet about the eighth week, and the vessel is then divided into the trunk of the pulmonary artery and the ascending aorta. The pulmonary artery becomes continuous with the now differentiated right ventricle; at its lower end it lies in front of the aorta, and then winds round it to its left side. The ascending aorta, again, becomes continuous with the left ventricle, and, though situated at its commencement behind the pulmonary trunk, it subsequently appears anterior to it and to the right side. That part of the arterial septum is last formed which lies nearest the base of the ventricles; and in connection with this circumstance it may be mentioned, that some cases of malformation of the human heart have been seen, in which the aorta and pulmonary artery directly communicated with each other, through a deficient formation of this part of the septum.

It has already been stated that the *truncus communis arteriosus* bifurcates anteriorly into the two ventral aortic roots, which lie at the sides of the primitive pharynx, and then arch backwards, parallel to the rudimentary spine, as the two primitive dorsal aortæ. The arches formed by these two vessels form the 1st pair of *Vascular Arches*. As the neck of the embryo elongates, these arches also elongate, and in their concavity four additional pairs of *vascular arches* form, successively from before backwards, and are named the 2nd, 3rd, 4th, and 5th pairs of vascular arches. All five pairs, however, are not present at the same time, for before the 5th pair appears, about the fourth or fifth week in the development of the human embryo, the 1st and often the 2nd pair have disappeared. The first pair of vascular arches are as far forward as the 1st visceral

arch, in which the lower jaw is developed, and the 2nd, 3rd, and 4th pairs are in the corresponding visceral arches. The 1st, 2nd, and 3rd pairs spring from the ventral aortic roots; the 4th pair from that part of the truncus communis which subsequently becomes the ascending aorta, and the 5th pair from the part of the truncus communis which becomes the trunk of the pulmonary artery. All five pairs of arterial arches join the primitive dorsal aortæ, and form, at their junction with it, the *dorsal aortic roots*. The primitive dorsal aorta is at first two distinct vessels lying parallel and close to each other; they subsequently coalesce in the dorsal and lumbar regions of the embryo, and form the descending thoracic and abdominal portions of the aorta, which is thus, as was demonstrated by Allen Thomson, a secondary vessel formed by the fusion of two originally distinct arteries. Two or three cases have been seen in which the fusion between the two primitive vessels has not been completed, and the aorta has been divided into two canals by a longitudinal septum. The descending thoracic and abdominal part of the aorta have numerous branches developed in connection with them, which supply the parietes of the thorax and abdomen, the pelvis, and the lower limbs. But further, two arteries are developed in the wall of the allantois, which become continuous through the iliac arteries with the abdominal aorta. During the later period of embryonic life they attain a large size, convey the blood to the placenta, and are named the hypogastric or umbilical arteries.

The vascular arches in the early human embryo have a general resemblance to the arrangement of the branchial arteries in the gills of fish and amphibia, but in man and the higher vertebrates gills are not formed in connection with them. In reptiles, birds, and animals they have a similar arrangement to what has just been described in the human embryo. In man, and all the higher vertebrates, the vascular arches undergo a metamorphosis as the development of the embryo advances. Some of the arches, as the 1st and 2d, atrophy and disappear, whilst others undergo a great increase in size, and give rise to those arteries which are known in human anatomy as the arch of the aorta, the right and left pulmonary arteries and ductus arteriosus, the innominate artery, the common, internal, and external carotid arteries, and the subclavian arteries.

In man, and all the other mammalia, the 4th left arch, and the part of the dorsal aortic root which connects the 4th and 5th left arches, undergo a great increase in size, in correspondence with the growth of the embryo, and forms the transverse part of the arch of the aorta, which arches above the root of the left lung, and consti-

tutes what is called a left aorta. The 4th right arch also increases in size, though not to the same extent as the left, and forms the innominate artery, and the first and second parts of the right subclavian artery of human anatomy; whilst the third part of this artery, with the axillary, seems to be a lateral twig, from the dorsal aortic root, that connects the 4th and 5th vascular arches. The left subclavian again is apparently in its whole extent a lateral branch of the dorsal aortic root, connecting the 4th and 5th vascular arches. The common carotid artery is formed by a great

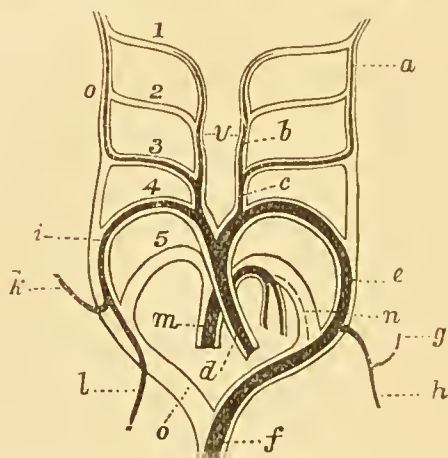


Fig. 159.—Diagram of the Vascular Arches, to illustrate their conversion into the great arteries (after Rathke.) 1 to 5, the five pairs of vascular arches; r, the two ventral aortic roots; oo, the right dorsal aortic root; a, internal carotid; b, external carotid; c, common carotid; d, the part of the truncus communis which develops into the ascending aorta; e, transverse part of arch of aorta; f, descending aorta; g and h, left vertebral and subclavian arteries; i and l, right subclavian; k, right vertebral; m, the part of the truncus communis which develops into the trunk of the pulmonary artery; n, the 5th left arch which gives off the right and left pulmonary arteries, and forms the ductus arteriosus represented by the dotted line in the figure. The shaded parts indicate the permanent vessels, whilst those left in outline, atrophy, and disappear.

increase in size of the ventral aortic root, which joins the 3rd and 4th vascular arches: the external carotid is a dilatation of the more anterior part of the same root connecting the 3rd with the 2nd, and the 2nd with the 1st vascular arch. The internal carotid artery is produced by a great increase in the size of the 3rd vascular arch, and of the dorsal aortic root between the 3rd and 2nd, and 2nd and 1st vascular arches. The descending thoracic aorta, as already stated, is formed by the fusion of the two dorsal aortic roots; whilst the ascending aorta is one of the two vessels into which the truncus communis is divided.

The trunk of the pulmonary artery is the other division of the truncus communis arteriosus. It is continuous with the 5th pair of vascular arches. Of these the 5th right arch atrophies, and disappears at an early period of embryonic life. The 5th left arch again increases in size, forms the *ductus arteriosus*, or Botalian duct, and conveys the blood directly from the trunk of the pulmonary artery into the aorta, immediately beyond the origin of the left subclavian artery. From the 5th left arch two collateral twigs arise, the one of which passes to the root of the right lung, the other to that of the left lung, and form the right and left branches of the pulmonary artery. After the birth of the child, when respiration by the lungs commences, the ductus arteriosus begins to close, and in the second or third week has shrivelled up into a fibrous cord; the right and left pulmonary arteries also increase in size, so as to convey all the blood of the right or pulmonic side of the heart into the lungs.

In birds and reptiles, the right pulmonary artery is developed from the right 5th vascular arch, and the left pulmonary artery from the left 5th vascular arch,* so that in these animals there are two Botalian ducts during foetal life, and in some families of reptiles these are found even in the adult.

In birds the arch of the aorta is developed from the 4th right vascular arch and right dorsal aortic root, and arches above the right bronchus, so that the aorta in this class is a right aorta. Sometimes in the human body the arch of the aorta follows the avian and not the mammalian type of development, and a right and not a left aorta is present.

In reptiles, again, both 4th vascular arches, with the corresponding parts of the dorsal aortic roots, persist, so that the aorta is a double aorta, an arch existing both on the right and left sides. A few cases have been seen in man in which the aorta possessed this reptilian arrangement.

But the vascular arches and aortic roots may undergo other metamorphoses than those above described, which may lead to the production of other variations in the

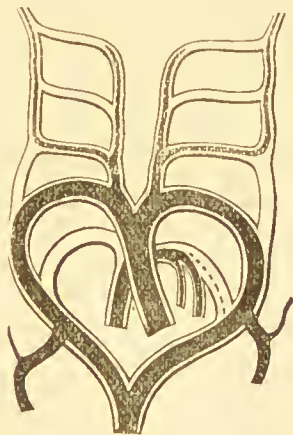


Fig. 160. Scheme of the mode of formation of a double arch of the aorta, through the persistence of both fourth vascular arches, and the immediately adjacent dorsal aortic roots.

arrangement of the great arteries, examples of which are occasionally seen in the human subject. It would be out of place in this elementary work to enter further into this matter, but I may refer for more complete information to my memoir on this subject in the *British and Foreign Medico-Chirurgical Review*, 1862.

The *Veins* that first appear in the development of the human embryo are the *omphalo-mesenteric* veins, which arise in the vascular area situated in the wall of the umbilical vesicle. These veins unite into a single trunk which opens into the primitive auricle. As the allantois grows out from the pelvic region of the body of the embryo to reach the chorion, and assist in the formation of the foetal placenta, two umbilical veins appear in its wall in about the fourth week of utero-gestation. In the fifth week one of these veins has disappeared, and the remaining one enlarges and forms the umbilical vein, which conveys the blood from the placenta to the embryo throughout the rest of foetal life. It joins at its proximal end the omphalo-mesenteric vein. As the umbilical vein lies in one part of its course in the region occupied by the liver, it becomes connected with the veins of the liver. The veins developed in connection with the spleen and abdominal portion of the alimentary canal are the splenic, gastric, and mesenteric veins, which, by their union, form the portal vein, and the portal is in direct communication with the umbilical vein. Veins develop in the rudimentary lower limbs, and in the pelvis, which become the femoral, external iliac, and common iliac veins, whilst the internal iliac are believed to be the lower ends of the two cardinal veins. The two common iliac veins join to form the inferior vena cava, which, as it ascends to the liver, receives the renal, capsular, and spermatic veins, and veins from the parietes of the abdomen. In the region of the liver it is connected to the umbilical vein by the *ductus venosus*, and it receives the hepatic veins. It opens into the auricle of the heart.

Two *cardinal* veins are developed in the thoracico-abdominal cavity, which return the blood from the Wolffian bodies and the walls of the trunk; and two *primitive jugular* veins are developed in the head and neck, which return the blood from these regions. The primitive jugular and cardinal vein on each side join in the cervico-thoracic region to form a vein called the *duct of Cuvier*, and the two ducts of Cuvier open into the auricle of the heart. The upper part of the primitive jugular subsequently becomes the external jugular vein. At its lower end the primitive jugular on each side is joined by veins, which become the internal jugular and sub-

clavian veins. The conjoined right jugular and subclavian veins form the right innominate vein. A *transverse communicating vein* is developed, which connects the right innominate with the conjoined left jugular and subclavian, and forms the left innominate vein. The two innominate veins are continuous below with the right duct of Cuvier, which has undergone a commensurate enlargement, and forms the right or persistent superior vena cava. The left duct of Cuvier does not undergo a commensurate increase in size, but almost entirely disappears, except at its lower end, which forms the coronary sinus, and opens into the right auricle. Traces of the vessel, however, as was pointed out by Marshall, exist in a small vein, which passes obliquely from this sinus along the wall of the left auricle, and in the vestigial fold of the pericardium.

The upper end of the right cardinal vein becomes the part of the vena azygos which joins the superior cava. The upper end of the left cardinal vein becomes the left superior intercostal vein, which usually joins the left innominate vein. The lower ends of the cardinal veins, as already stated, form the internal iliac veins. The intermediate portions of the cardinal veins are said to atrophy, and their place is taken by two *posterior vertebral veins*, which receive the intercostal veins, and form the left azygos vein, and the lower part of the right azygos, which afterwards become continuous with the upper end of the azygos developed from the right cardinal vein.

In birds, and in some mammals, the left duct of Cuvier persists, and forms a left superior cava. A few cases have also been seen in man in which the left duct of Cuvier had not atrophied, and a right and a left superior vena cava opened into the right auricle; in these cases, the transverse communicating, or left innominate vein, was either altogether absent or only feebly developed.

Whilst these changes are going on in the heart, and in the arrangement of the great vessels, the position of the heart is also altered. With the formation and elongation of the neck, the heart is further removed from the head, in close proximity to which it had first appeared, and becomes enclosed, by the development of the ribs and sternum, in the thoracic cavity. The carotid arteries and jugular veins at the same time become greatly elongated. As the pneumogastric nerves, which supply branches to the heart, accompany these vessels, they become elongated likewise. In the early embryo each pneumogastric gives off its recurrent laryngeal nerve opposite the fifth vascular arch, around which the nerve turns in its ascent to the larynx. When the fifth right arch com-

pletely disappears, the nerve then turns around the first part of the subclavian, which represents the 4th right arch. As the fifth left arch, however, persists throughout life as the obliterated ductus arteriosus, the left recurrent nerve bends immediately below it before it ascends behind the transverse part of the arch of the aorta.

Owing to the progressive changes which take place in the heart during its formation, the circulation of the blood through it is necessarily much modified in the course of its development. When the heart is in its primitive stage of single cavities, the blood flows from the veins successively into the auricle, ventricle, and truncus communis arteriosus, as a single stream. But when the ventricle is divided into two chambers, each communicating with a distinct artery, derived from the division of the truncus communis, then the blood is divided in these parts of the heart and great vessels into two streams. As the division of the auricle into two chambers takes place at a later period than that of the ventricle, the subdivision of the blood into two streams does not take place so early in that cavity. In the later stages of intra-uterine life, when the left duct of Cuvier has atrophied, the superior and inferior venæ cavæ have attained their proportional size, and the auricular septum has become developed, though with the foramen ovale patent, the circulation of the blood through the heart is as follows :—

The blood of the inferior cava, which consists not only of the impure venous blood from the infra-diaphragmatic parts of the body, but of the blood of the umbilical vein from the placenta, flows into the right auricle, but is at once directed by the Eustachian valve through the foramen ovale into the left auricle. It then flows into the left ventricle and the ascending and transverse parts of the aorta, from which it principally proceeds through the carotid and subclavian arteries into the head, neck, and upper limbs, only a small proportion apparently passing into the descending aorta.

The blood of the superior cava again is solely venous, which is returned by this great vein from the head, neck, upper limbs, and walls of the chest. It flows into the right auricle, where it may acquire a slight admixture with the blood of the inferior cava. By this auricle it is propelled into the right ventricle, and thence into the pulmonary artery. Only a small part of this venous blood passes into the right and left pulmonary arteries; the greater part flows through the ductus arteriosus into the descending aorta, by which it is distributed, not only to the infra-diaphragmatic parts of the body, but by the hypo-gastric and umbilical arteries to the placenta. In the fœtus, therefore, the blood which circulates

through the heart and arteries is mixed blood. The precise differentiation of the blood of the two sides of the heart into a right venous side, and a left arterial side does not take place until after the birth of the child, when the pulmonary respiration being established, the ductus arteriosus becomes obliterated, and the foramen ovale becomes closed.

The *Ductless Glands* for the most part, though not entirely, are developed from the mesoblast.

The *Spleen* arises from a mass of cells situated in connection with the meso-gastric fold of the stomach. These cells belong to the mesoblast, and form originally, as Peremeschko has shown, a mass common to both spleen and pancreas. A constriction then forms which separates the mass into a left, or splenic, and a right, or pancreatic portion. Into the pancreatic portion a prolongation of the hypoblast lining of the primitive alimentary canal passes, but not into the splenic portion. An artery grows into the spleen mass from the aorta, and the collection of cells differentiates into the proper textures of the spleen.

The *Supra-renal capsules* arise, as was pointed out by Goodsir, from a mass of cells situated between the two Wolffian bodies. These cells belong to the mesoblast layer of the embryo. Kölliker considers that the two capsules are originally one organ, which subsequently separates into two lateral portions. At first the supra-renal capsules are larger than the kidneys, but their subsequent growth is not so rapid, so that the kidneys soon surpass them in size.

The *Thymus* arises, according to Simon, in a membranous substance situated parallel and close to the carotid arterics. This membrane is probably derived from the mesoblast.

The *Thyroid* arises from a rounded mass of mesoblast cells situated in relation to the first pair of vascular arches. W. Müller states that a prolongation of the hypoblast lining of the pharynx is continued into it. It is probable, therefore, that, whilst the vascular connective tissue of the thyroid is of mesoblast origin, the cellular lining of its vesicles is derived from the hypoblast. This difference in the origin of the thyroid, as compared with the thymus and spleen, is an additional argument to that derived from their structural differences, against the physiological identity of these organs.

The *Pituitary gland* consists of two lobes developed from very different parts. The posterior lobe is a downward prolongation of the floor of the third cerebral ventricle, with which it is continuous through the infundibulum; it is derived therefore from the epi-

blast. The anterior lobe, as has been shown by the recent observations of W. Müller, Götte, and Mihalkovics, is an upward prolongation from the upper part of the back of the embryo mouth, in front of the anterior end of the chorda dorsalis. This buccal prolongation is continuous with the epiblast lining of the mouth, but is subsequently cut off from it by the growth of the cartilaginous floor of the skull. The two lobes then fuse together into a single organ, which is lodged in the pituitary fossa of the sphenoid bone.

The development of the *Pineal gland* has not been definitely ascertained; but from its relation to the optic thalami it evidently arises in connection with the thalami from the thalamencephalon, or posterior division of the anterior cerebral vesicle. As it is so closely invested by the pia mater, some have supposed that it might be developed in connection with that membrane.

CHAPTER VIII.

THE LARYNX, OR ORGAN OF VOICE.

THE Larynx, or Organ of Voice, is the upper end of the windpipe, which, whilst performing the function of a respiratory tube, is especially modified in its construction for the production of the voice.

The larynx lies in the middle of the anterior part of the neck, in front of the pharynx, and immediately below the hyoid bone. It passes downwards to opposite the body of the sixth cervical vertebra, where it becomes continuous with the trachea. It is covered by the sterno-hyoid, sterno-thyroid, thyro-hyoid, and omo-hyoid muscles, cervical fascia and skin; and the lateral lobes of the thyroid body, with the upper ends of the two common carotid arteries, lie at its sides. It forms a tube, the wall of which is composed of a framework of cartilages, jointed together and movable on each other by the action of special muscles. Within the tube are the vocal cords, by the vibrations of which the voice is produced. It is lined by a glandular mucous membrane, and is supplied by blood-vessels and nerves.

Cartilages of the Larynx.

The cartilages of the larynx are nine in number, and form its framework. They consist of three single cartilages,

the thyroid, the cricoid, and the epiglottis; and of three pairs of cartilages, the two arytenoid, the two cornicula laryngis, and the two cuneiform cartilages.

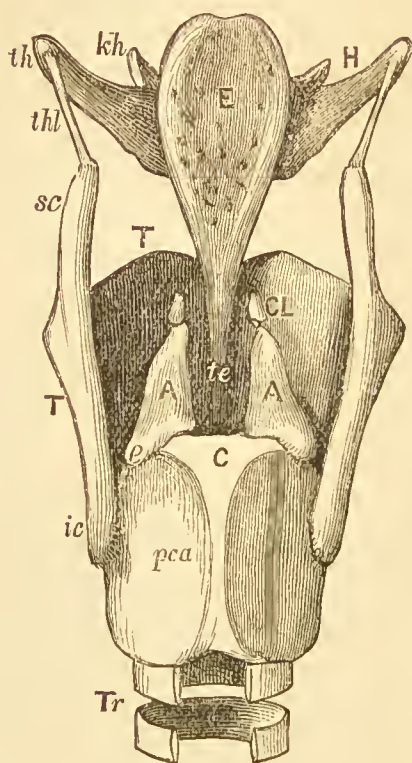


FIG. 161.—Cartilages of the Larynx seen from behind. E, epiglottis; T, thyroid cartilage; C, cricoid cartilage; AA, arytenoid cartilages; CL, cornicula laryngis; Tr, trachea; H, hyoid bone; *kh*, kerato-hyoid or small cornu; *th*, thyro-hyoid, or great cornu; *thl*, thyro-hyoid ligament; *sc*, superior cornu, and *ic*, inferior cornu of thyroid cartilage; *te*, thyro-cricoid ligament; *e*, external process of arytenoid cartilage; *pca*, surface of origin of posterior crico-arytenoid muscle.

The THYROID, or shield-like cartilage, is the largest of the cartilages of the larynx. It is situated anteriorly, and laterally, and consists of two quadrilateral plates or *alæ*, which are united together by their anterior borders, where they form, especially in the neck of a man, a projecting angle, or prominence in the middle line of the front of the neck, familiarly known as Adam's apple, the *pomum Adami*

(fig. 168). From this border of union the plates project

backwards, diverging from each other to form a retreating angle, and enclosing the smaller cartilages of the larynx. Each plate is marked on its outer surface by an oblique ridge for the attachment of the thyro-hyoid and sterno-thyroid muscles, whilst the inner surface is smooth, and for the most part covered by mucous membrane. The upper border of each plate is attached to the hyoid bone by a broad fibro-elastic membrane, the *thyro-hyoid membrane*, and the lower border is united to the upper border of the cricoid cartilage by the *crico-thyroid membrane*. The posterior border gives attachment to the palatopharyngeus and the stylo-pharyngeus muscles, and is prolonged into two cornua. The superior cornu is attached to the tip of the great cornu of the hyoid by a rounded elastic band, the *thyro-hyoid ligament*, in which a nodule of cartilage, *cartilago triticea*, is often situated; the inferior cornu is short, and articulates with the side of the cricoid cartilage by a movable joint.

The CRICOID, or ring-like cartilage, is the lowest cartilage of the larynx, and completely surrounds the tube. Its vertical diameter posteriorly is about one inch, but anteriorly not more than $\frac{1}{4}$ inch. Its outer surface possesses posteriorly a mesial vertical ridge, to the side of which is a depression for the origin of the posterior crico-arytenoid muscle (fig. 161). On each lateral aspect of the cartilage is an articular facet for the inferior cornu of the thyroid cartilage, anterior to which is a surface for the attachment of the crico-thyroid muscle. The inner surface of the cricoid cartilage is smooth, and lined by mucous membrane. Its lower border is almost horizontal, and is attached by membrane to the first ring of the trachea.

Its upper border slopes from behind downwards and forwards, and possesses a pair

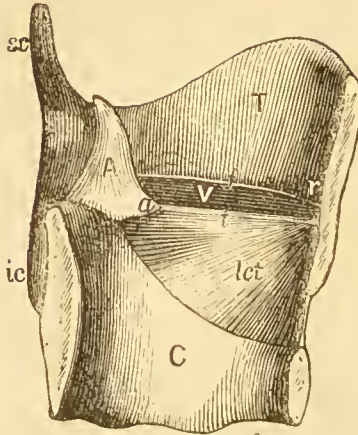


FIG. 162.—View of the interior of the left half of the Larynx, after the removal of the mucous membrane. T, thyroid cartilage; *sc*, its superior, and *ic*, its inferior cornu; *r*, its retreating angle; A, arytenoid cartilage; *a*, its anterior or vocal process; *t*, true, and *f*, false vocal cord; V, the position of the ventricle; C, cricoid cartilage; *lct*, lateral crico-thyroid membrane or crico-thyro-arytenoid ligament.

of articular facets posteriorly for the two arytenoid cartilages; whilst in front of these facets it gives attachment to the crico-thyroid membrane and lateral crico-arytenoid muscle. The cricoid cartilage is connected to the thyroid by a pair of crico-thyroid joints and the crico-thyroid membrane. The *crico-*

thyroid membrane is a fibro-elastic structure attached below to the upper border of the cricoid cartilage; it consists of a mesial and of two lateral

portions; the mesial part is attached above to the lower border of the middle portion of the thyroid cartilage; whilst each lateral portion runs upwards in close relation to the mucous lining of the larynx, and terminates in a thin free superior border, the inferior or true vocal cord; as the anterior end of this cord is attached to the middle of the retreating angle of the thyroid cartilage, and the posterior end to the anterior or vocal process at the base of the arytenoid cartilage, it may be more precisely called the *inferior crico-thyro-arytenoid ligament* (fig. 162). The *crico thyroid joint* is formed on each side between the inferior cornu of

the thyroid and the side of the cricoid cartilage, between which is a diarthrodial joint, enclosed by a *capsular ligament*, and lined by a synovial membrane.

The EPIGLOTTIS is a leaf-like plate of yellow fibro-cartilage situated in front of the upper opening of the larynx. Its elongated stalk passes vertically downwards behind the body of the hyoid, and the projecting angle of the thyroid cartilage to be attached to the inner surface of this angle by the *thyro-epiglottic ligament* (fig. 161). The blade of the leaf is ovoid in form, and projects upwards behind the tongue. Its surfaces are directed forwards and backwards, and are covered by mucous membrane, which is prolonged from the anterior surface to the back of the tongue as the *glosso-epiglottidean folds*; beneath these folds is an elastic membranous band, the *glosso-epiglottidean ligament*, which stretches from the root of the tongue to the anterior surface of the epiglottis; and on a still deeper plane is the *hyo-epiglottidean ligament*, an elastic membrane, which attaches the front of the epiglottis to the body, and great cornua of the hyoid. The posterior surface, concave from side to side, is free, and possesses a prominence called the *cushion* (figs. 163, 164). The upper border is free and rounded; but from the lateral borders the mucous membrane is prolonged downwards and backwards, as far as the cornicula laryngis and arytenoid cartilages, to form a pair of folds, the *aryteno-epiglottidean folds of mucous membrane*, which form the lateral boundaries of the superior opening of the larynx. The cartilage of the epiglottis is pitted by numerous depressions, in which mucous glands are lodged.

The ARYTENOID, or pyramidal cartilages, two in number, are placed on the posterior part of the upper border of the cricoid cartilage. Each is a three-sided pyramid, about half an inch in height, and a quarter of an inch in width. The base articulates with the cricoid, and two of its angles are prolonged into well-marked processes: the *external* or *muscular* process is directed backwards and outwards, and gives attachment to the tendons of insertion of the lateral and posterior crico-arytenoid muscles; the *anterior* or *vocal* process is directed forwards, and gives attachment to the true vocal cord. The apex of the cartilage is directed upwards, and articulates with the corniculum laryngis. The posterior surface is concave, and gives attachment to the arytenoid muscle: the inner surface is smooth, and covered by the mucous membrane; the anterior surface gives attachment to the superior or false vocal cord, and to the thyro-arytenoid muscle. The base of the arytenoid cartilage is connected to the cricoid by a *capsular ligament*, lined by a synovial membrane, and a band of fibres extending from the back of the arytenoid to the back of the cricoid has been named the *posterior crico-arytenoid ligament*. The *false vocal cords*, or *superior thyro-arytenoid ligaments*, pass from the anterior surface of each arytenoid cartilage to the retreating angle of the thyroid; and the *true vocal cords*, or *inferior thyro-arytenoid ligaments*, pass from the anterior vocal process of the arytenoid to the retreating angle of the thyroid cartilage (fig. 162).

The CORNICULA LARYNGIS, or Cartilages of Santorini, are two small nodules articulated to the apices of the arytenoid cartilages, the connection being effected by a *cap-*

sular ligament, lined by a synovial membrane (figs. 161, 163.) The cornicula are formed of yellow fibro-cartilage.

The CUNEIFORM cartilages, or Cartilages of Wrisberg, are two thin plates of yellow elastic cartilage, placed one in each aryteno-epiglottidean fold of mucous membrane.

Interior of the Larynx.

The tube of the larynx, or the glottis, communicates above with the pharynx, and below with the trachea. The *superior opening* of the larynx is somewhat triangular in form, with the base in front and the apex behind. It is bounded in front by the epiglottis; on each side by the aryteno-epiglottidean fold of mucous membrane; behind by the cornicula laryngis, the apices of the arytenoid cartilages, and the fold of mucous membrane passing between them. The *inferior opening* is circular in form, like the tube of the trachea, with which it is continuous.

The mucous lining of the larynx is elevated into folds, which correspond in position to the false and true vocal cords; the arrangement of the cords may be seen when the larynx is looked into through its superior opening, or when a mesial incision is made longitudinally through the posterior wall, and the two sides of the tube slightly separated from each other (fig. 163). Two pairs of vocal cords may then be seen extending, one above the other, at the sides of the mesial plane, in the antero-posterior direction from the thyroid to the arytenoid cartilages. The *superior pair*, or the *false vocal cords*, consist of thin fibres attached anteriorly to the retreating angle of the thyroid cartilage, and posteriorly to the anterior surface of the arytenoid cartilage: these fibres are covered by a fold of the mucous

membrane, which presents a convex contour on the surface next the mesial plane of the larynx, whilst the opposite surface bounds the laryngeal pouch. The *inferior pair*, or *true vocal cords*, have a sharp straight border superiorly,

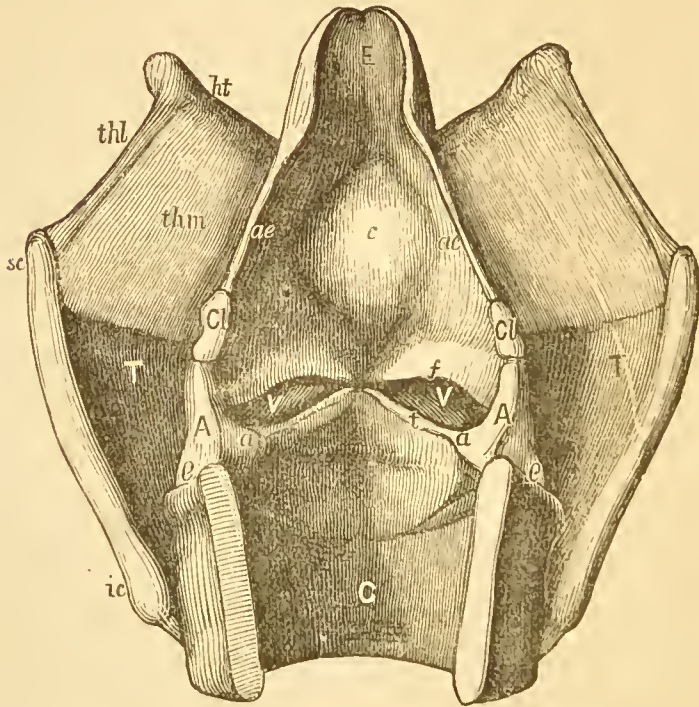


FIG. 163.—View of the interior of the Larynx, obtained by making a mesial vertical incision through the posterior wall. E, epiglottis; c, its cushion; ht, great cornu of hyoid; thm, thyro-hyoid membrane; thl, thyro-hyoid ligament; T, alæ of thyroid cartilage; sc, its superior, and ic, its inferior cornu; A, arytenoid cartilages; Cl, cornicula laryngis; ae, ae, aryteno-epiglottidean folds of mucous membrane; C, cricoid cartilage; f, false vocal cord; V, ventricle of larynx; t, true vocal cord; a, a, anterior or vocal processes of arytenoid cartilages; ec, external or muscular processes.

whilst their inner surfaces are flattened. They consist of fibres extending from the retreating angle of the thyroid to the anterior vocal process of the arytenoid cartilage, and each is so blended with the lateral portion of the crico-

thyroid membrane as to form its free upper border. The mucous membrane which covers them is thin and free from glands. The slit between the two true vocal cords and the inner surfaces of the two arytenoid cartilages, is in the mesial plane, and is named the *rima glottidis*, or *chink* of the larynx. That part of the rima which lies between the vocal cords has been called the *vocal glottis*, whilst that situated between the arytenoid cartilages is the *respiratory glottis* (fig. 166). The long or antero-posterior diameter of the rima is nearly 1 inch in the larynx of a man, and about $\frac{3}{4}$ -inch in that of a woman. Its width or transverse diameter varies with the position of the vocal cords, and the variations in its width modify its shape. When the cords are separated to the greatest extent, the rima is lozenge-shaped ; when they are moderately asunder, it is an elongated triangle, with the base behind and the apex in front ; when they are brought in contact with each other the rima is closed.

Between the superior and inferior vocal cord on each side is an elongated deep depression, the *sinus*, or *ventricle* of the larynx, which is lined by mucous membrane ; the floor of this ventricle is concave immediately to the outer side of the true vocal cord. A prolongation of the ventricle, named the *pouch of Morgagni* or *saccule of the larynx*, passes upwards, to the outer side of the superior vocal cord, as high as the level of the upper border of the thyroid cartilage ; the pouch is lined by mucous membrane continuous with the mucous lining of the ventricle of the larynx, and in its outer wall is the thyro-arytenoid muscle.

If a vertical transverse section be made through the larynx immediately in front of the arytenoid cartilages the

ANATOMY.

vocal cords are transversely divided, and it will be seen,

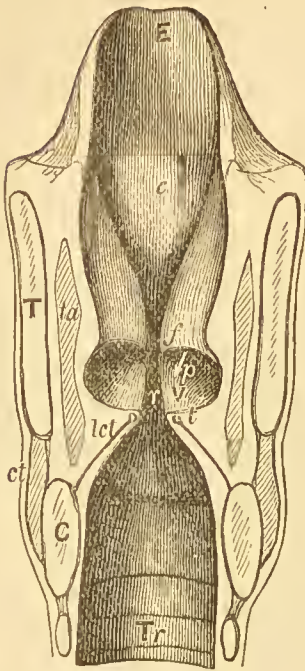


FIG. 164.—Vertical transverse section through the Larynx. E, epiglottis; c, its cushion-like prominence; T, left ala of thyroid cartilage; ta, thyro-arytenoid muscle; C, cricoid cartilage; cl, crico-thyroid muscle; f, false vocal cord; t, true vocal cord; v, ventricle of larynx; p, points upwards into laryngeal pouch; r, rima glottidis; lct, lateral crico-thyroid membrane seen in section; Tr, trachea.

as was pointed out by J. Wyllie, that the interior of the larynx possesses the form of two wedge-shaped spaces (fig. 164). The upper wedge extends from the superior orifice of the larynx to the ventricles of the larynx: the lower wedge from the lower orifice of the larynx to the true vocal cords. Experiments made by Wyllie have shown that the glottis can be closed, during an inspiratory effort, not only by the action of the muscles which bring the true vocal cords into apposition with each other; but by the pressure of the column of air, in the upper wedge-shaped space of the larynx, on the concave floor of the ventricles, immediately external to the true vocal cords. Whilst closure of the glottis, during an

expiratory effort may be occasioned by the pressure of the column of air in the lower wedge-shaped space, inflating the pouches of the larynx, and forcing the false vocal cords together. The larynx contains in its interior therefore two valves, one of which can control the entrance, the other the exit of air.

Muscles of the Larynx.

The muscles of the larynx are arranged in two groups, an extrinsic and an intrinsic.

The *extrinsic* muscles are divided into a supra-hyoid and an infra-hyoid group. The supra-hyoid muscles are the digastric, stylo-hyoid, mylo-hyoid, and genio-hyoid. The infra-hyoid are the omo-hyoid, sterno-hyoid, sterno-thyroid, and thyro-hyoid. These muscles act on the entire larynx through their insertion into the hyoid bone, and through the attachment of that bone to the thyroid cartilage. Their description naturally comes, therefore, into that of the muscles acting on the hyoid. As the sterno-thyroid and thyro-hyoid muscles have a direct attachment to the alæ of the thyroid cartilage, they will be described here.

Sterno-thyroid arises from the back of the manubrium sterni, and the first costal cartilage; it ascends in front of the trachea, and is inserted into the oblique line on the outer surface of the thyroid cartilage.

Thyro-hyoid arises from the lower border of the great cornu and the body of the hyoid bone, and is inserted into the same oblique line to which the sterno-thyroid is attached.

From the attachment of these muscles to the thyroid cartilage, they can fix it, and put it in a better position to serve as a surface of origin for those intrinsic muscles of the larynx, which arise from it.

The *intrinsic* muscles of the larynx arise from and are inserted into the cartilages of the larynx, and by their action diminish or increase the tension of the vocal cords, diminish or increase the size of the rima glottidis, or affect the position of the epiglottis and the size of the superior

aperture of the larynx. These muscles should be examined with reference to their action on the crico-thyroid joints, the crico-arytenoid joints, and the epiglottis.

The muscles which act on the crico-thyroid joints are the pair of crico-thyroid muscles and the pair of thyro-arytenoid muscles.

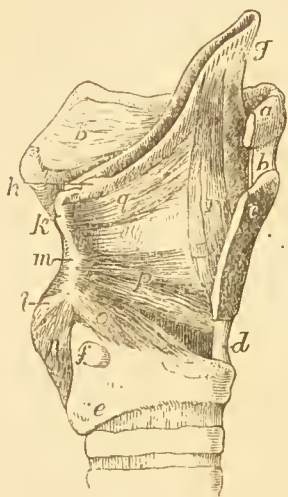


FIG. 165.—The muscles of the Larynx as seen after the removal of the right ala of the thyroid cartilage. *a*, hyoid bone; *b, b*, thyro-hyoid membrane; *c*, thyroid cartilage; *d*, middle crico-thyroid membrane; *e*, cricoid cartilage; *f*, surface of articulation with thyroid; *g*, epiglottis; *h*, cornuiform cartilage; *k*, corniculum laryngis; *l*, muscular process of arytenoid cartilage; *m*, the posterior and *o*, lateral crico-arytenoid muscles; *p*, thyro-arytenoid muscle; *q*, oblique aryteno-epiglottidean muscle; *r*, thyro-epiglottidean muscle.

The *Crico-thyroid* muscle arises from the side of the cricoid cartilage as far forward as its anterior middle line; its fasciculi pass backwards and upwards, and are inserted into the lower border of the thyroid cartilage and the anterior border of its inferior cornu. The two crico-thyroids diverge from each other, and leave uncovered the middle division of the crico-thyroid membrane.

The *Thyro-arytenoid* muscle arises from the inner surface of the thyroid cartilage close to its retreating angle: it passes almost horizontally backwards in close relation to the outer wall of the pouch of the larynx and to the true vocal cord, and is inserted into the vocal process at the base of the arytenoid cartilage, into the an-

terior surface of the same cartilage, and by a few fibres into the true vocal cord.

The crico-thyroid muscles increase the tension of the vocal cords. As to the mode in which this tension is occasioned there is a difference of opinion. It is usually believed that the crico-thyroid muscles rotate the thyroid cartilage about a transverse axis, passing horizontally through the two crico-thyroid joints, and depress the anterior border of the thyroid cartilage so as to elongate the vocal cords in front. But some anatomists hold that the thyroid cartilage is fixed by the action of the thyro-hyoid muscles, that the crico-thyroid muscles then rotate the cricoid cartilage on the thyroid, by drawing the front of the cricoid cartilage upwards, which depresses the back of the cricoid and the arytenoid cartilages, and

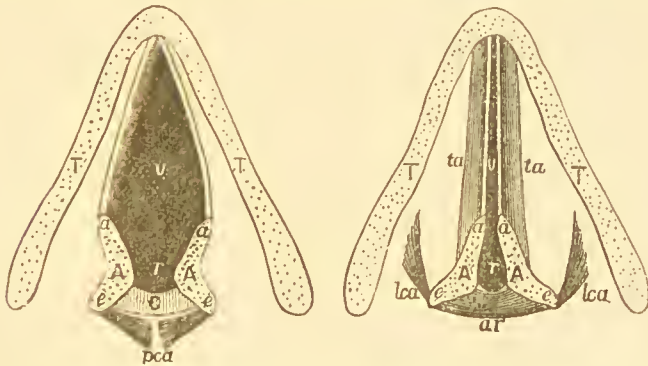


FIG. 166.—Diagram of the Rima Glottidis, to illustrate the action of the muscles on it. A transverse section has been made through the larynx on a level with the true vocal cord and the bases of the arytenoid cartilages. TT, alæ of thyroid cartilage; AA, arytenoid cartilages; aa, their vocal, and ee, their muscular processes; v, vocal, and r, respiratory part of glottis. In the right hand figure the rima is shown as almost closed by the action of lca the pair of lateral arytenoids and ar, the arytenoid muscle, ta, ta, the pair of thyro-arytenoid muscles. In the left hand figure the rima is shown widely open by the action of pca, the pair of posterior crico-arytenoid muscles; C, the upper border of the cricoid cartilage.

elongates the posterior ends of the vocal cords. The thyro-arytenoid muscles approximate the opposite ends of the vocal cords, and thus relax them, by drawing the thyroid

cartilage upwards and backwards, but owing to the attachment of some fibres to the vocal cord, local tension may be given to certain parts of it. The fibres attached to the anterior surface of the arytenoid cartilage may roll it inwards so as to bring the two cords together, and narrow the rima glottidis.

The width of the rima glottidis is altered by the movements of the arytenoid cartilages, which rotate about a vertical axis passing through the crico-arytenoid joints. The cartilages are rotated outwards, the vocal processes and vocal cords are separated from each other, and the rima glottidis is widened by the pair of

Posterior crico-arytenoid muscles, which arise from the depressed surfaces on the back of the cricoid cartilage (fig. 161), and pass upwards and outwards to be inserted into the external or muscular process at the base of each arytenoid cartilage.*

The arytenoid cartilages are rotated inwards, the vocal cords are approximated, and the vocal part of the rima glottidis is narrowed by the pair of

Lateral crico-arytenoid muscles, which, being under cover of the sides of the thyroid cartilage, arise from the upper border of the side of the cricoid, pass backwards and upwards to be inserted into the external or muscular process at the base of each arytenoid cartilage.

The arytenoid cartilages are drawn together, and the width of the respiratory part of the rima glottidis is narrowed, by the single

* Merkel described a small *Kerato-cricoid* muscle as occasionally extending, but on one side only, from the lower part of the back of the cricoid cartilage to the inferior cornu of the thyroid. I found it to be present 7 times in 32 subjects, and to be occasionally present on both sides.

Arytenoid muscle, which arises from the posterior concave surface of one arytenoid cartilage, passes transversely across the mesial plane, to be inserted into the corresponding surface of the other cartilage.

The epiglottis is drawn backwards and depressed by the pair of oblique aryteno-epiglottidei, and the thyro-epiglottidei muscles.

The *Oblique aryteno-epiglottidei* muscles consist of the oblique fibres situated superficial to the arytenoid muscle. They arise near the external or muscular tubercle at the base of the arytenoid, pass obliquely upwards across the mesial plane to the apex of the opposite arytenoid cartilage, and then ascend in the aryteno-epiglottidean fold of mucous membrane. The oblique aryteno-epiglottidean and arytenoid muscles are arranged around the superior orifice of the larynx like a sphincter, and by their contraction the size of this opening is diminished.

Thyro-epiglottidei consist of fibres which arise from the inner surface of the thyroid cartilage near the retreating angle, and ascend to the side of the epiglottis.

The glottis is shut, during the act of swallowing, not only by the depression of the epiglottis, as described on p. 89, but by the closure of the rima glottidis, due to the approximation of the arytenoid cartilages and the true vocal cords.

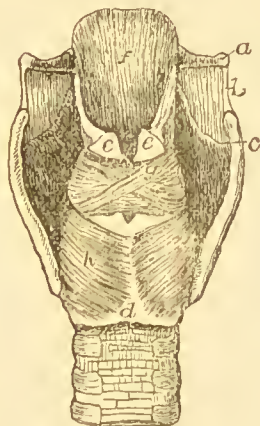


FIG. 167.—The posterior muscles of the Larynx. *a*, hyoid bone; *b*, thyro-hyoid ligament; *c*, thyroid cartilage; *d*, cricoid cartilage; *e, e*, arytenoid cartilages; *f*, epiglottis; *g*, oblique aryteno-epiglottidean muscles; *h*, posterior crico-arytenoid muscle.

The free edges of the vocal cords are thrown into vibrations in the production of the voice. The modifications which take place in their degree of tension, and in the size of the rima in connection with the production of the notes, and the elevation or lowering of their pitch, are questions which are more appropriately discussed in works on physiology.

Mucous Membrane of the Larynx.

The larynx is lined by a mucous membrane, continuous above, through the superior opening, with the mucous lining of the pharynx, and below, through the inferior opening, with that of the trachea. It is thin, especially where it covers the true vocal cords, but in the aryteno-epiglottidean folds it is thicker and the sub-mucous tissue is looser: it does not possess a high degree of vascularity. Its surface is covered by a ciliated columnar epithelium, intermingled with goblet-shaped cells; except near its superior orifice, and over the true vocal cords, in which localities it is squamous. The sub-epithelial connective tissue of the mucosa contains a quantity of elastic fibres. Numerous racemose glands are found opening on the surface of the laryngeal mucous membrane. They are very abundant on the back of the epiglottis, in which they are lodged in small pits, and in the walls of the laryngeal pouches. Collections of lymphoid tissue are also found in the subepithelial tissue of the mucosa.

Vessels and Nerves of the Larynx.

The larynx receives its supply of blood from the superior laryngeal branches of the superior thyroid arteries, which pierce the thyro-hyoid membrane; from the crico-thyroid branches of the same arteries, which form an arch on the crico-thyroid membrane, and from the inferior laryngeal branches of the inferior thyroid arteries, which pass to the lower and posterior part of the larynx. Veins correspond to these different arteries. Lymphatics are distributed in the mucous and submucous tissues.

The nerves of the larynx are the superior and inferior laryngeal branches of the pneumogastric. The superior laryngeal nerve divides into an external and an internal branch. The external branch is small, and descends to supply the crico-thyroid muscle. The internal branch pierces the thyro-hyoid membrane, and divides into two parts; the upper or epiglottic branch supplies the mucous covering of the epiglottis, the aryteno-epiglottidean and hyo-glossal folds of mucous membrane; the lower part supplies the mucous lining of the middle and lower parts of the larynx, and gives a branch to the arytenoid muscle. The inferior or recurrent laryngeal nerve supplies branches to all the intrinsic muscles of the larynx except the crico-thyroid. It also communicates with the superior laryngeal nerve, and gives some small twigs to the mucous membrane.

CHAPTER IX.

RESPIRATORY SYSTEM.

THE Respiratory System is composed of organs, which are engaged in the interchange of gases between the blood and the atmospheric air. Through their instrumentality, the blood acquires oxygen from the air, imparts to it carbonic acid and watery vapour, and becomes changed from impure venous into pure arterial blood. In man and the higher vertebrates the interchange of gases is effected through the medium of a long branching tube, called the Windpipe, and of two vascular spongy organs, the Lungs. But as the windpipe has no direct communication with the exterior of the body, and opens superiorly into the pharynx, the atmospheric air has to pass, through either the nose or mouth into the pharynx, before it can enter the windpipe. The nose is the proper passage for its transmission, and constitutes therefore a part of the respiratory apparatus. As the nose is also an organ of sense, its anatomy has been described under that head (p. 322).

The process of respiration consists of two acts, with intermediate pauses—breathing in and breathing out. Breathing in, or Inspiration, consists in drawing air into

the lungs, so as to expand those organs. Breathing out, or Expiration, consists in the expulsion from the lungs of a portion of the air which they contained. By the regular alternation of these two acts, during extra-uterine life, the air in the lungs is constantly being renewed, and fresh portions of air are brought into relation with the stream of blood, as it is propelled through the capillaries of the lungs by the action of the right, or pulmonic side, of the heart. The movements of respiration are in a great measure effected by the agency of numerous muscles acting on the osseo-cartilaginous framework of the thorax. A general description of the action of these muscles has been already given on p. 78.

As the lungs occupy a large portion of the cavity of the chest, and have important relations to its walls, it will be advisable, before describing them, to give an account of the construction, shape, and size of the thorax, and to point out the regions into which it is customary to divide it.

THORAX.

The CAVITY of the THORAX or CHEST is intermediate in position, in size, and in the extent of mobility of its walls to the cavities of the cranium and abdomen. It contains not only the two lungs and the terminal part of the wind-pipe, but the heart, with the great blood-vessels which pass to and from it, some large nerves, the œsophagus, and the thoracic duct. It is very completely walled in by bones, cartilages, muscles, membranes, and skin.

Thirty-seven bones enter into the formation of the osseous walls of the thorax, viz., 12 dorsal vertebræ,

12 pairs of ribs, and the sternum. The dorsal vertebræ are situated in the middle of its posterior wall. Their bodies are united together by the intervertebral discs, and anterior and posterior common ligaments; their articular processes by capsular ligaments; their laminae by the ligamenta subflava; and their spines by the supra and inter spinous ligaments. The sternum is situated in the middle of the anterior wall of the chest. It consists of three pieces, which ultimately fuse together into a single bone. The twelve ribs on each side are articulated behind to the dorsal vertebræ. They project at first backwards, downwards, and outwards; they then arch downwards, forwards, and inwards, and are continuous at their anterior ends with the costal cartilages. The first costal cartilage prolongs the first rib downwards and inwards to the side of the manubrium sterni. The second continues the second rib horizontally inwards to the side of the joint between the manubrium and body of the sternum. The cartilages of the third rib to the tenth inclusive slope upwards and inwards, and become gradually more vertical in their direction, as one passes downwards in the series. The cartilaginous termination of the seven upper ribs, on each side articulate with the side of the sternum. The cartilaginous terminations of the eighth, ninth, and tenth ribs do not reach the side of the sternum; but as they are jointed together, and as the eighth cartilage is jointed with the seventh, the seventh to the sixth, and the sixth to the fifth, they are indirectly connected to that bone, and the movements of the ribs, of which they are the terminations, can thus influence the movements of the sternum. The cartilaginous terminations of the eleventh and twelfth ribs

come to free ends in the muscles of the wall of the abdomen.

The ribs are all jointed behind by their heads to the bodies of the vertebræ, and they all, except the eleventh and twelfth, possess tubercles, which are jointed to the transverse processes of their corresponding dorsal vertebræ. The intervals between the ribs, or intercostal spaces, are occupied by the external and internal intercostal muscles, and by an anterior and a posterior intercostal fibrous membrane. The intercostal spaces are eleven in number on each side of the thoracic wall. Each space is not of equal width in its entire length, for the borders of the ribs which bound it are not parallel with each other. They are the widest opposite the junction of the osseous and cartilaginous part of the costal arch, but from this spot they diminish in width from before backwards. The width of the upper series of spaces is greater than that of the middle and lower. The lower two intercostal spaces, however, remain of equal width throughout.

The *External* or *Superficial Intercostal* muscle forms a layer extending, from the tubercles of the ribs posteriorly, as far as, or almost as far as, the junction of the osseous and cartilaginous part of the rib anteriorly. Its fasciculi are short; they arise from the lower border of one rib, and pass obliquely downwards and forwards to be inserted into the upper border of the rib situated immediately below.

The *Internal* or *Deep Intercostal* muscle forms a layer extending from the anterior ends of the costal cartilages as far back as the angles of the ribs. Its fasciculi arise from the inner margins of the lower border of the rib and

costal cartilage, and pass obliquely downwards and backwards to be inserted into the upper border of the rib situated immediately below.

The *Anterior Intercostal Fibrous Membrane* stretches between the lower border of one costal cartilage, and the upper border of the cartilage immediately below it. It lies superficial to the intercartilaginous part of the internal intercostal muscle. In the case of the sternal ribs, the membrane reaches from the anterior border of the external intercostal muscle to the side of the sternum, whilst in the case of the a-sternal ribs, it connects their cartilages without reaching the sternum.

The *Posterior Intercostal Fibrous Membrane* stretches between the lower border of the neck and shaft of one rib and the upper border of the neck and shaft of the rib immediately below. It reaches from the posterior border of the internal intercostal muscle as far as the head of the rib; it is in relation to the inner surface of the posterior fibres of the external intercostal muscle, and between the two are the intercostal vessels and nerve.

The *Triangulis Sterni* muscle lies behind the costal cartilages of the lower true ribs. It arises from the side of the xiphi-sternum and the sternal ends of the sixth and seventh costal cartilages; it passes obliquely upwards and outwards in separate digitations to be inserted into the costal cartilages, from the second to the fifth inclusive, at their junction with the bony part of the rib.

The *Intra- or Sub-costal* muscles are irregular in number and size. They are situated on the inner surface of the ribs in the region of the angles, and are chiefly found attached to the lower ribs. Their fibres run obliquely

downwards and backwards, like those of the internal intercostals, and correspond in length to two intercostal spaces.

The thorax is usually compared in shape to a truncated cone, the apex of which is above, the base below. It is rounded at the sides, but flattened both in front and behind. The truncated apex, or thoracic inlet, is bounded behind by the first dorsal vertebra, laterally by the first pair of ribs, and in front by the manubrium or pre-sternum. As the vertical diameter of the sternum is less than that of the series of dorsal vertebræ, the upper end of the sternum does not reach so high as the first dorsal vertebra, and the plane of the thoracic inlet slopes obliquely from above downwards and forwards. In expiration the upper border of the manubrium is opposite the body of the third dorsal vertebra, or the disc between it and the second dorsal vertebra; in inspiration it is raised to opposite the body of the second vertebra. Through the thoracic inlet the trachea, œsophagus, and some large veins, and nerves descend into the thorax, and the great arteries and thoracic duct ascend into the neck. Owing to the obliquity of the plane of the thoracic inlet, the parts in the middle of the lower part of the neck, though above the sternum, lie anterior to the bodies of the first and second dorsal vertebræ.

The base of the thorax is much more capacious than the apex. It slopes from the xiphi-sternum downwards, outwards, and backwards along the cartilages of the seventh, eighth, ninth, and tenth ribs, as far as the cartilaginous tip of the eleventh rib, and then slopes upwards, backwards, and inwards along the twelfth rib to the twelfth dorsal verte-

bra. The point of the xiphi-sternum is opposite the body of the twelfth dorsal vertebra in expiration, but in inspiration is raised to opposite the body of the eleventh vertebra.

The base of the thorax is filled in by the diaphragm, which forms the floor of the thorax and the vaulted roof of the abdomen. At the end of an expiration, the summit of the diaphragm mounts as high as the level of the sternal end of the fourth intercostal space on the right side, but not quite so high on the left; from this summit level it slopes downwards and backwards to the costal origins of the muscle. The thoracic surface of the diaphragm is therefore convex. The diaphragm is perforated to allow of the passage of the œsophagus, nervi vagi, aorta, and sympathetic nervous cords downwards into the abdomen, and of the thoracic duct, vena azygos and inferior vena cava upwards into the thorax.

The antero-posterior diameter of the thorax is less than either the transverse or vertical diameters. The antero-posterior diameter in the mesial plane, *i.e.*, the sterno-vertebral diameter, though it increases from above downwards, is less than it is on one side of the sternum, for the projection forwards of the bodies of the dorsal vertebræ, and the backward slope of the posterior ends of the ribs, cause a considerable hollow at the side of the vertebral bodies, in which the posterior border of the lung is lodged. The transverse diameter rapidly increases from the first to the 6th or 7th ribs, and then diminishes somewhat down to the 12th rib. The vertical diameter is much greater, owing to the more backward slope of the diaphragm at the costo-vertebral than at the costo-sternal wall. All the diameters

increase during the inspiratory, and diminish during the expiratory movements. The capacity of the thorax in men is greater than in women. In women, during respiration, a greater range of movement takes place in the upper part of the thoracic walls than in men, in whom the lower part of the chest passes through a wide range of movement. In young children again the diaphragm, much more than the thoracic walls, is concerned in inspiration, and the abdominal viscera are therefore much depressed, and the anterior abdominal wall is pushed forwards. Modifications of the natural form of the thorax may arise from congenital malformations of its walls: from external pressure artificially applied, as tight lacing: from diseases of its walls, as in curvatures of the spine: or from diseases of the viscera contained in its cavity, as from pleuritic effusions, emphysema, aneurisms or other tumours, &c.

When the bones of the shoulder girdle, and the great muscles which pass from them to the walls of the chest are in position, and when these are covered by the fascia and skin, the external configuration of the chest is very materially modified. The outward projection of the shoulders, more especially in men, causes the transverse diameter to be greater at the upper part of the chest than lower down; and the pectoral and scapular muscles add materially to the thickness of the anterior and posterior walls of the chest. In order to assist in localising precisely the position of the important organs within the chest, it is customary to map out the surface of the integument into certain areas or regions, and to apply to these regions descriptive names. Thus, the region corresponding to the sternum is the *sternal*

region, and it is divided into an *upper sternal* and a *lower sternal* by a line drawn across the front of the bone on a level with the upper border of the third pair of costal cartilages. The fossa immediately above the manubrium sterni is the *epi- or supra-sternal* fossa. The region corresponding to the inner half of the clavicle is the *clavicular* region: that which lies immediately above it is the *supra-clavicular* region, and that which extends downwards from the clavicle to the lower border of the third rib is the *infra-clavicular* region. The region which extends from the lower border of the third rib to the lower border of the sixth rib is the *mammary* region, and that which extends downwards from the lower border of the sixth rib to the inferior limit of the thoracic wall is the *infra-mammary*. The clavicular, infra-clavicular, mammary and infra-mammary regions are bounded internally by a line corresponding to the outer border of the sternum, and externally by a line drawn vertically downwards from the middle of the clavicle to the inferior limit of the thoracic wall. In the mammary region are situated the mammary gland and nipple. In women the mamma occupies almost the whole of the mammary region, and the nipple usually lies superficial to the fifth rib, and about $4\frac{1}{3}$ inches from the middle line of the sternum. In men the mamma is a rudimentary organ, and the position of the nipple is more variable. Luschka found in 60 men examined, that it was placed 44 times between the fourth and fifth ribs, 6 times on the fifth rib, 8 times on the fourth rib, and twice between the fifth and sixth ribs; whilst Gruber found it in 95 males, 43 times on the fifth rib, 31 times on the fourth intercostal space, 12 times on the fourth rib, and 9 times on the fifth intercostal

space. It varies also in position on the two sides of the same chest. As a rule, it lies in men about $3\frac{3}{4}$ inches from the middle line of the sternum.

At the lateral wall of the chest are the axillary and infra-axillary regions. The *axillary* extends from the apex of the axilla to a line corresponding to the lower border of the sixth rib; and the *infra-axillary* from that line to the edge of the false ribs, where they limit the thoracic wall inferiorly.

Several regions are placed on the posterior wall of the chest. The *scapular* region corresponds to the scapula, and in its vertical diameter reaches from the second to the seventh or eighth rib: the *infra-scapular* region extends from the inferior angle of the scapula to the twelfth rib: the *inter-scapular* region lies between the vertebral borders of the two scapulæ; it varies in its transverse diameter with the position of the arms; for, when they are drawn forward, the vertebral borders of the two scapulæ are further asunder, than when the arms hang pendulous at the sides, or are pushed backwards: the *supra-scapular* region extends from the upper border of the scapula to a little above the level of the first rib. The size of both the supra-scapular and infra-scapular regions is modified with the elevation or depression of the shoulders.

The portion of the anterior wall of the chest which lies superficial to the heart is called the *cardiac* region. It comprises the whole of the lower sternal region and portions of the right and left mammary regions. Owing to the greater portion of the heart being situated to the left than to the right of the mesial plane of the thoracic cavity, it projects more into the left than into the right mammary

region. The right ventricle corresponds to the lower sternal region, but on the one side passes slightly into the right mammary region, and on the other more extensively into the left mammary. The right auricle is also in the right mammary and lower sternal regions, but the left auricle and ventricle correspond to the left mammary region. The vertical diameter of the cardiac region is from the level of the upper border of the third pair of costal cartilages to that of the sixth pair; its transverse diameter is from a line somewhat internal to the left nipple to a finger's breadth to the right of the sternum. The relations of the aortic and auriculo-ventricular openings to the wall of the chest has already been given on p. 407. It may further be stated, that the relation of the heart to the walls of the thorax varies slightly with the position of the body, with the quantity of blood in the heart, and with the stage of the respiratory process. In a full inspiration the heart is depressed about half an inch, owing to the descent of the diaphragm.

THE WINDPIPE.

The Windpipe is the tube which transmits the atmospheric air from the pharynx into the lungs. It is divided into the larynx, the trachea, and the two bronchi. As the larynx has been described in Chapter VIII., the trachea and bronchi now require description.

The TRACHEA is situated in the middle of the anterior part of the neck, and in the upper part of the back of the thoracic mediastinum. It is continuous above with the

cricoid cartilage of the larynx, and extends from opposite the body of the 6th cervical vertebra to the level of the body

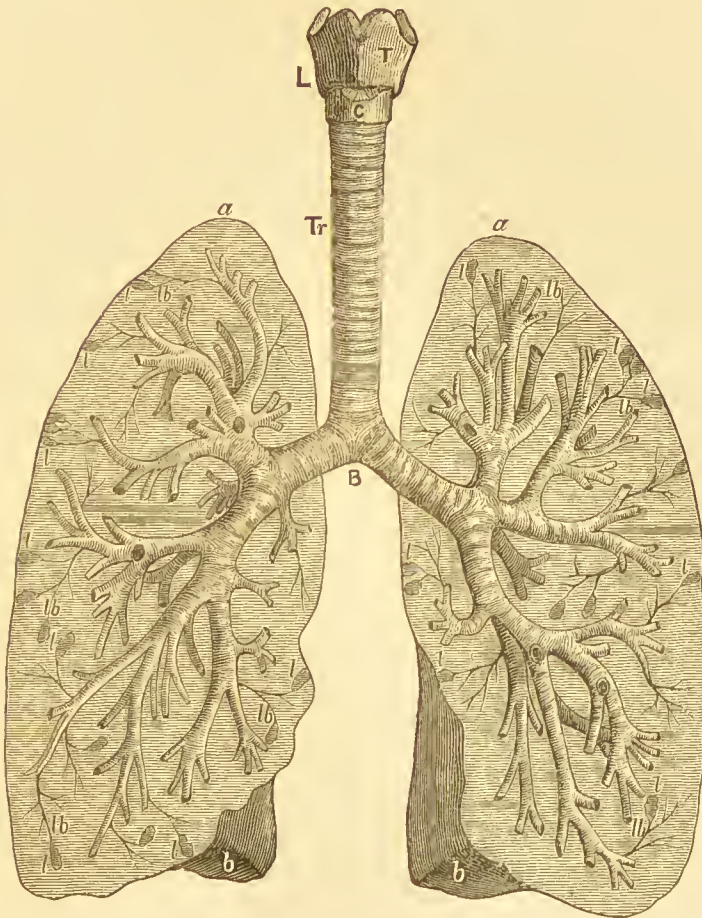


FIG. 168.—The Windpipe and Lungs. L, larynx; T, thyroid cartilage; C, cricoid; Tr, trachea; B, bifurcation into bronchi; a, apex, and b, base of each lung. The ramifications of the bronchi within the lungs are shown; lb, lb, lobular bronchial tubes; l, l, l, lobules.

of the 4th or sometimes the 5th dorsal vertebra, where it

bifurcates into the two bronchial tubes.* It is between four and five inches long, and is nearly an inch in its greatest width. Anteriorly and laterally it is cylindrical in form, but it is flattened on its posterior surface. It corresponds to the supra- or epi- sternal fossa in the neck, and to the interscapular region on the posterior surface of the chest, on a level with the upper 4 or 5 dorsal vertebræ. In the neck it has anterior to it the sterno-hyoid and sterno-thyroid muscles, cervical fascia and skin; opposite its third and fourth rings, it is crossed by the isthmus of the thyroid body, and in front of the lower rings are the inferior thyroid veins: at its sides are the common carotid arteries, lateral lobes of the thyroid gland, and recurrent laryngeal nerves; behind it is the œsophagus. In the thorax it lies behind the manubrium sterni, the sterno-hyoid, and the sterno-thyroid muscles, the fatty remains of the thymus gland, the left innominate vein, the transverse part of the aortic arch, the origins of the innominate and left common carotid arteries, and the deep cardiac plexus of nerves; on each side is the pleural membrane, but in addition on the right side is the termination of the innominate artery, and on the left side are the left common carotid and subclavian arteries, and the left vagus with its recurrent branch: behind is the œsophagus.

The BRONCHI are two in number, a right and a left.

* Many descriptive writers state that the trachea extends from the 5th cervical to the 3d dorsal vertebra. The observations of Braune, on sections through the neck in frozen bodies, show that the cricoid cartilage lies opposite the 6th cervical vertebra. The bifurcation also takes place lower down than the 3d dorsal vertebra. But it should be remembered that the position of the trachea is modified by changes in the position of the head. When the head is thrown back the trachea is drawn up; when the chin is approximated to the sternum the trachea is depressed.

They proceed from the bifurcation of the trachea, and pass obliquely downwards and outwards to the roots of their respective lungs. The left bronchus is longer and more oblique than the right, and enters the back of the root of the left lung, below the pulmonary artery, but above the pulmonary vein. The right bronchus, though shorter, is wider than the left, and enters the back of the root of the right lung above the pulmonary artery. The vena azygos arches forwards immediately above the right bronchus to join the superior cava; whilst the left bronchus lies within the arch of the aorta. In the angle formed by the bifurcation of the bronchi is a cluster of lymphatic glands. The bronchi correspond to the interscapular region on the posterior surface of the thoracic wall, on a level with the fifth and sixth dorsal vertebræ.

Structure of the Trachea.

The wall of the trachea is formed of cartilage, fibro-elastic membrane, muscular tissue, a submucous coat, and a mucous membrane. The *cartilage* is arranged in the form of imperfect rings, from sixteen to twenty in number, separated by narrow intervals. Each ring is about two-thirds of a circle, and is placed at the front and sides of the trachea, but is absent posteriorly (fig. 161). Sometimes a cartilage divides into two branches, at other times two adjacent cartilages fuse together at their posterior ends. The lowest tracheal cartilage has a process prolonged backwards, at the angle of bifurcation into the two bronchi.

The *fibro-elastic membrane* connects together the upper and lower borders of adjacent cartilages, also the upper

tracheal cartilage with the cricoid cartilage, and completes the wall of the trachea posteriorly by passing between the posterior ends of the cartilaginous rings.

The *muscular tissue* consists of non-striped fibres, which lie in the posterior wall of the trachea, under cover of the fibro-elastic membrane. They pass for the most part transversely, and not only extend between the posterior ends of the cartilaginous rings, but lie also opposite the intervals between them.

The *submucous coat* is distinguished by containing, especially in the posterior wall of the trachea, longitudinal bundles of elastic fibres. In this coat are situated numerous compound racemose glands, the branches of which on section are like cylindrical tubes: they are lined by a columnar epithelium, and the excretory duct opens on the free surface of the mucous membrane.

The *mucous membrane* lines the inner surface of the trachea, and is elevated on the posterior wall into longitudinal folds, which correspond to the bundles of elastic fibres in the submucous coat. The free surface of the mucous membrane is covered by a layer of ciliated columnar epithelium, amidst which goblet-shaped cells are interspersed. Between the deeper ends of the ciliated epithelium, smaller spindle-shaped, or rounded, cells are found in considerable numbers. Deeper than the epithelium is a muscular layer, the *muscularis mucosæ*. Lymphoid tissue is also found diffused throughout the sub-epithelial tissue of the mucous membrane, and occupying the intervals between the vesicles of adjacent racemose glands.

The trachea is supplied with blood by branches from the laryngeal branches of the inferior thyroid arteries. Lym-

phatic vessels form plexuses in the mucous and submucous coats. Fine nerves, derived from the pneumogastric and sympathetic, are distributed to it, in connection with which microscopic ganglia have been seen.

THE PLEURÆ.

Each lung is situated in, and occupies the greater part of, one lateral half of the cavity of the thorax. It is invested by a serous membrane, the Pleura; and the wall of the chest, bounding the space in which the lung is contained, is lined by a prolongation of the same serous membrane. Like the serous membranes elsewhere, the pleura consists, therefore, of a *visceral part* investing the organ, and a *parietal part* lining the wall of the cavity in which the organ is lodged. The pleural investment of the lung is called the *pulmonic pleura*. The pleural lining of the cavity has different names applied to different portions of its extent. That which lines the inner surface of the ribs, costal cartilages, and intercostal muscles, is the *costal pleura*; that which covers the upper surface of the diaphragm is the *diaphragmatic pleura*: that which is prolonged for one inch, or rather more, above the level of the first rib into the root of the neck, is the *cervical pleura*; that which covers the lateral surface of the pericardium, and forms the lateral boundary of the mediastinum, is the *mediastinal pleura*; whilst a fold of the pleura, prolonged downwards from the root of the lung to the diaphragm, forms the broad ligament of the lung, *ligamentum latum pulmonis*. These several terms simply express topographical divisions of one and the same membrane: thus the pleura costalis

is continuous above with the cervical pleura, and below with the diaphragmatic pleura. Where the costal cartilages articulate with the sternum, the costal pleura comes in contact with the back of that bone, and is then reflected backwards, as the mediastinal pleura, on the outside of the pericardium, from which it is prolonged in front of the root of the lung to become continuous with the pulmonic pleura. Where the ribs articulate behind with the spine, the pleura is prolonged on the sides of the vertebral bodies, from which the right pleura is reflected forward on the back of the root of the lung, to become continuous with the pulmonic pleura, but the left pleura; before it reaches the back of the root of its lung, is prolonged over the left aspect of the descending thoracic aorta.

The cervical prolongation of the pleura forms the dome-shaped summit of the parietal pleura. It corresponds to the apex of the lung, and is in relation by its outer surface to the scalenus anticus muscle and the subclavian artery.

The parietal part of the right pleura is more extensive than that of the left, for not only does it pass behind the sternum up to the mesial line of that bone, or sometimes even to the left of that line; but owing to the greater projection of the heart to the left than to the right of the mesial thoracic plane, it covers a larger proportion of the upper surface of the diaphragm. The costo-parietal part of the left pleura, again, whilst it reaches the left border of the upper part of the sternum, does not pass so far forward as the lower part of the body of that bone. The costal pleurae do not reach quite so far down as the costal origins of the diaphragm, so that these origins, as well as

the surface of the diaphragm, to which the pericardium is attached, are not covered by the pleural membranes.

The two pleural membranes are perfectly independent of each other, and although they both extend towards the mesial plane of the thorax, they do not come in contact with each other, except in some cases, where they touch immediately behind the body of the sternum. The interval between the two pleural membranes occupies the mesial plane, or sterno-vertebral diameter of the thoracic cavity, and is named the *mediastinum*, *mediastinal space*, or *interpleural space*. The mediastinum is bounded laterally, therefore, by the two pleuræ; it is not an empty space, but is occupied by the heart and pericardium, and by certain structures situated both in front of and behind the pericardium. The heart and pericardium fill up the greater portion of the interpleural space, and the region they occupy is called the *middle mediastinum*. Owing to the projection of the heart to the left, the middle mediastinum extends more to the left than to the right of the mesial plane. As the phrenic nerves lie between the sides of the pericardium and the mediastinal pleura, they are also placed in the middle mediastinum. The narrow interval between the front of the pericardium and the back of the sternum is the *anterior mediastinum*, which inclines from above downwards to the left of the mesial plane. It contains the left triangularis sterni muscle, the origins of the sterno-hyoid and sterno-thyroid muscles, in the infant and child the thymus gland, and in the adult the lobes of fat into which the gland has degenerated; also some loose areolar tissue. The wider interval between the back of the pericardium and the front of the bodies of the vertebræ

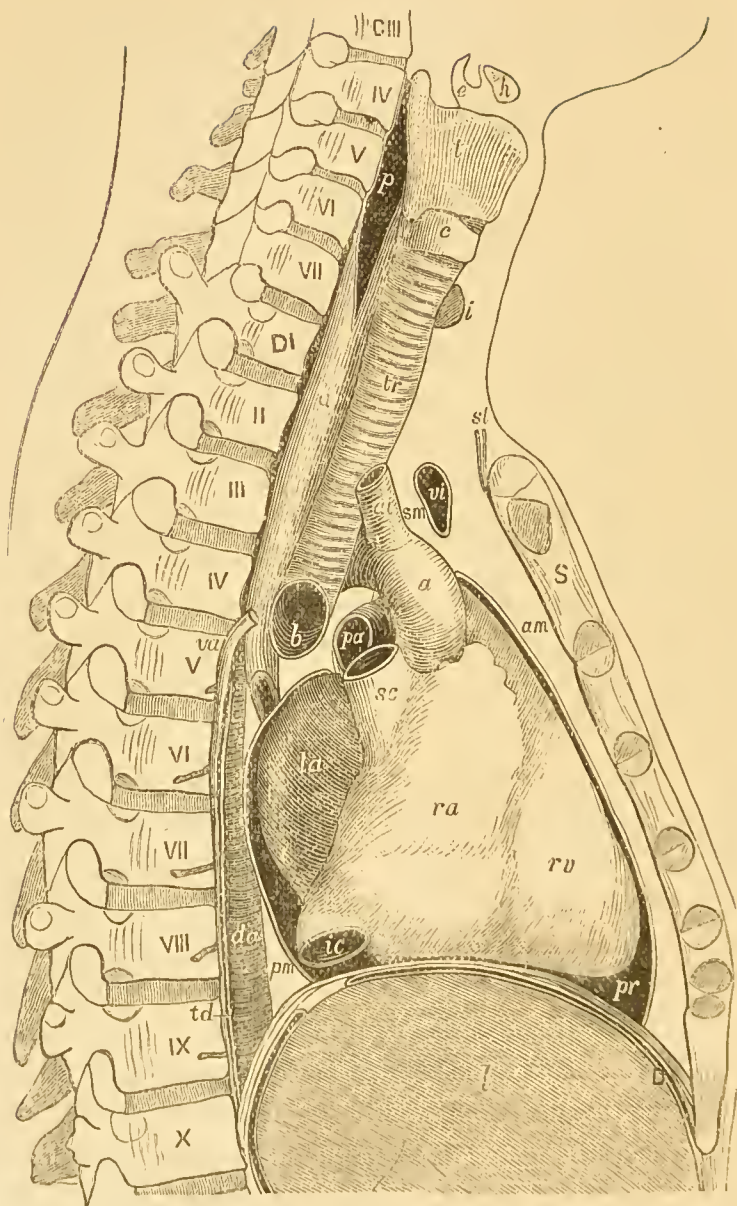


FIG. 169 —View of the Sterno-vertebral region of the chest, or the Mediastinum Thoracis. S, sternum; D, diaphragm; CIII to VII, cervical vertebræ; DI to X, dorsal vertebræ; *am*, anterior mediastinum; *pm*, posterior mediastinum; *sm*, superior mediastinum. The middle mediastinum is occupied by the pericardium, *pr*, and by the heart, of which the following parts are shown; *ra*, right auricle; *rv*, right ventricle; *la*, left auricle; *sc*, superior vena cava; *ic*, inferior vena cava; *a*, ascending aorta; *ai*, innominate artery; *pa*, right branch of pulmonary artery. In the posterior mediastinum are shown *da*, descending thoracic aorta; *va*, vena azygos; *td*, thoracic duct; *æ*, æsophagus. *tr*, trachea; *vi*, left innominate vein; *st*, sterno-hyoid and sterno-thyoid muscles. *p*, pharynx; *t*, thyroid cartilage; *c*, cricoid; *e*, epiglottis; *h*, hyoid bone; *i*, isthmus of thyroid body; *l*, liver.

is the *posterior mediastinum*. It contains the descending thoracic aorta, the œsophagus, and nervi vagi, the vena azygos, thoracic duct with lymphatic glands, and the splanchnic nerves. As the pericardium does not extend so high as the level of the top of the sternum, the interpleural space between the manubrium sterni and the higher dorsal vertebræ lies above the pericardium, and J. Struthers has suggested that the name *superior mediastinum* should be given to it. It contains the two innominate veins, the innominate, left common carotid, and left subclavian arteries, the upper thoracic portion of the phrenic, pneumogastric and cardiac nerves, a part of the left recurrent laryngeal nerve, the trachea, and the upper thoracic part of the œsophagus and thoracic duct.

The pleura, like other serous membranes, possesses two surfaces, an attached surface and a free surface. By its attached surface the pleura is connected by areolar tissue to the ribs, intercostal muscles, diaphragm, pericardium, and lung. The free surface of the parietal pleura is smooth, and in apposition with the corresponding free surface of the pulmonic pleura. These two free surfaces glide on each other as the lungs and thoracic walls rise and fall during inspiration and expiration; and, as the surfaces are lubricated by a little serous fluid, the movement is facilitated. This fluid occupies a scarcely appreciable interval between the free surfaces of the parietal and visceral pleuræ, which interval forms the so-called *pleural cavity*. The pleural cavity becomes distinct when any cause operates to push the lung from the wall of the chest; such as the introduction of air into the pleural cavity, either through an external wound, or from rupture of the lung;

or the effusion of fluid into the cavity, in the course of inflammation of the pleura ; either of these causes would push the lung backwards towards the spine, and occasion a great interval between the pulmonic and parietal parts of the pleura. But even in the healthy chest a modification in the relations of the pulmonic to the parietal pleura takes place in some localities. For as, during expiration, the lung does not pass either so far forwards or downwards, as during inspiration, the lung leaves the parietal pleura along its line of reflection from the ribs to the diaphragm, and from the sternum to the side of the pericardium, so that at the end of an expiration the smooth surface of the diaphragmatic and the mediastinal pleura is in apposition along these lines with the smooth surface of the costal pleura.

The pleura is supplied with blood by the intercostal, internal mammary, and bronchial arteries, which ramify in the sub-endothelial layer of connective tissue. Lymphatic vessels form fine networks in the same layer, and communicate through microscopic stomata with the pleural cavity. Nerves pass to the pleura both from the phrenic nerve and from the thoracic ganglia of the sympathetic cord.

It is not uncommon to find along the line of reflection of the pleura from the ribs to the diaphragm, and from the diaphragm to the side of the pericardium, folds of the pleural membrane containing lobules of fat ; and on the costal wall of the chest large lobules of fat are often developed beneath the parietal pleura. These folds have been called *pleural villi*, and they resemble the appendices epiploicæ, to be afterwards described, in the abdominal cavity.

THE LUNGS.

The Lungs are two in number and are situated one in each cavity of the thorax. Each lung is usually described

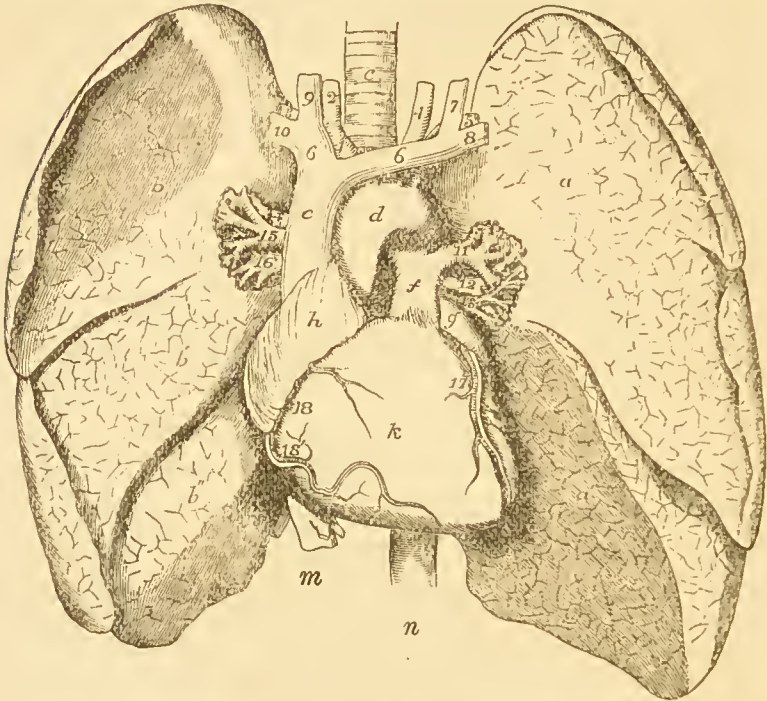


FIG. 170.—The Thoracic Viscera. In this diagram the lungs are turned to the side, and the pericardium removed to display the heart. *a*, upper, *a'*, lower lobe of left lung; *b*, upper, *b'*, middle, *b''*, lower lobe of right lung; *c*, trachea; *d*, arch of aorta; *e*, superior vena cava; *f*, pulmonary artery; *g*, left, and *h*, right auricle; *i*, right, and *k*, left ventricle; *m*, inferior vena cava; *n*, descending aorta; 1, innominate artery; 2, right, and 4, left carotid artery; 3, right, and 5, left subclavian artery; 6, 6, right and left innominate vein; 7 and 9, left and right internal jugular veins; 8 and 10, left and right subclavian veins; 11, 12, 13, left pulmonary artery, bronchus, and vein; 14, 15, 16, right bronchus, pulmonary artery, and vein; 17 and 18, left and right coronary arteries.

as having a conical form; it possesses a base, an apex, an outer surface, an inner surface, an anterior border, a posterior border, and an inferior border.

The *base* of the lung is concave, rests on the convex

upper surface of the diaphragm, and reaches much lower down behind than in front: the *apex* is rounded, and reaches into the root of the neck from one inch to one and a half inch above the first rib. The *external* or *costal surface* is much the larger of the two surfaces; it is convex, and adapted to the curvature of the ribs: the *internal* or *mediastinal surface* is concave, and adapted to the convex lateral surface of the pericardium; about the middle of this surface, but much nearer to the posterior than to the anterior border, is situated the root of the lung. The *anterior* or *sternal border* is thin, and fits in between the back of the sternum and the front of the pericardium: the *posterior* or *vertebral border* is thick and rounded, and occupies the deep hollow at the side of the vertebral bodies; this border possesses a longer vertical diameter than any other part of the lung. The *inferior* or *diaphragmatic border* forms the boundary between the base and the external and internal surfaces of the lung: in the greater part of its extent it fits between the ribs and the costal origins of the diaphragm. On all its aspects the exterior of the lung is in close relation to the parietal pleura, which relation it always preserves in the healthy chest, as it rises in inspiration, or falls in expiration. The contact of the lung with the parietal pleura is ensured by the pressure of the column of air in the windpipe and air-cells.

Each lung is divided into two *lobes* by a deep fissure, which, beginning at the posterior border about three inches below the apex, and on a level with the vertebral end of the third rib, extends through its substance, obliquely downwards and forwards, as far as the anterior border, or the anterior end of the inferior border. The *upper lobe* is

smaller than the *lower lobe*, and, from the direction of the oblique fissure, lies both above and in front of it. The apex and the whole, or the greater part, of the anterior border belong to the upper lobe: the greater part of the posterior border and of the base to the lower lobe. In the right lung a second fissure, which does not exist in the left lung, is also present. It commences at the oblique fissure, runs almost horizontally forwards to the anterior border of the lung, and separates the lower part of the upper lobe as a distinct lobe, called the third or *middle lobe* of the right lung. The right lung is still further distinguished from the left by being more hollowed out at its base, owing to the arch formed by the right half of the diaphragm being higher than that of the left, so that the vertical diameter of the right is not so long as that of the left lung. But the transverse diameter of the right lung is more than that of the left, for the greater projection of the heart and pericardium, to the left than to the right of the mesial plane, causes the mediastinal surface of the left lung to be more concave than the corresponding surface of the right lung. The anterior border of the right lung is much more nearly straight than that of the left, in which this border presents a semilunar notch below the level of the fourth rib, which corresponds to the position of the heart.

The lungs have extensive relations to the walls of the chest, and even to structures at the root of the neck. The apex of each lung lies in the supra-clavicular and supra-scapular regions, and is marked by a slight groove corresponding to the position of the subclavian artery, from which it is separated by the cervical prolongation of the

pleura. The bulk of the upper lobe is placed in the clavicular, infra-clavicular, mammary, axillary, and scapular regions. The middle lobe of the right lung is in the right mammary region. The lower lobe of each lung is in the infra-mammary, infra-axillary, scapular, and infra-scapular regions. The anterior border of each lung overlaps the front of the pericardium, and extends into both the upper and lower sternal regions, but the anterior border of the left lung does not pass so far into the lower sternal region as the corresponding border of the right lung. The posterior borders of the two lungs lie in the interscapular region. During inspiration the anterior border passes further forwards into the upper and lower sternal regions than during expiration, and the base of each lung, with the descent of the diaphragm, extends further down into the infra-mammary, infra-axillary, and infra-scapular regions. As the base of the lungs rests on the diaphragm they are necessarily brought into relation, through that muscle, with viscera situated in the costal zone of the abdomen; thus the right lung is in relation to the liver, and the left lung to the liver, stomach, and spleen.

The *Root* of the lung is composed of the important structures, which pass into, or emerge from, the interior of the lung. It consists of the large air tube, or bronchus, of the pulmonary artery, and the pulmonary veins, the bronchial artery and bronchial vein, the pulmonary nerves, the pulmonary lymphatic vessels, and the bronchial lymphatic glands. The bronchus is placed at the back of the root of each lung; in the root of the right lung it is the highest object, but in the root of the left lung it lies below the pulmonary artery. It is accompanied by the bronchial

artery and vein, by nerves and lymphatics. The pulmonary veins are anterior and inferior to the pulmonary artery in the

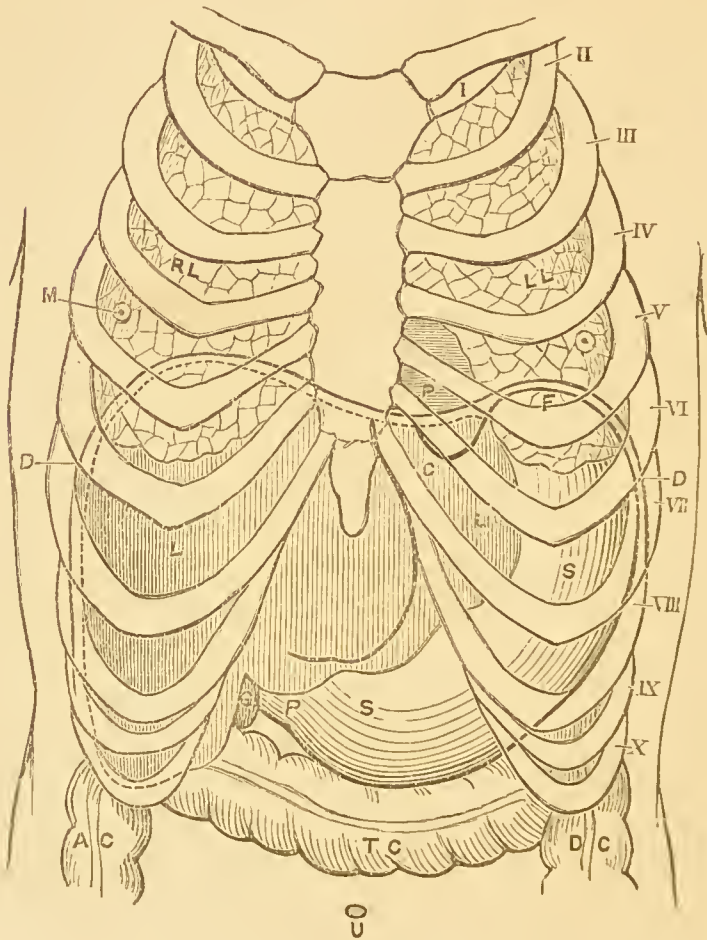


FIG. 171.-- The Lungs and their relations to the diaphragm, liver, and stomach. II, to X, second to tenth ribs; DD, diaphragm; RL, right, and LL, left lung; P, pericardium; S, S, stomach; F is placed superficial to its fundus; P, its pylorus; C is over the cardiac orifice; L, L, the liver; G, gall bladder; AC, ascending, TC, transverse, and DC, descending colon; U, umbilicus; M, right nipple. Modified from Lushka.

root of each lung. The posterior pulmonary nervous plexus lies at the back of the root, and the anterior pulmonary

nervous plexus is at the front of the root of the lung. Some areolar tissue connects these various objects together, and the whole are surrounded by the pleural membrane, as it passes from the region of the mediastinum to become continuous with the pulmonic pleura.

The vena azygos arches above the root of the right lung; the aorta above that of the left. The phrenic nerve passes in front of the root of each lung, but the root of the right lung has also the superior vena cava in front of it. The nervus vagus descends behind the root of each lung, but the root of the left lung has also the descending thoracic aorta behind it.

The lungs are light, spongy organs, and contain, after the child has begun to breathe, a quantity of air, so that they float on water. When roughly handled they crepitate, or emit a crackling sound, owing to the air being squeezed out of the air vesicles by the pressure of the fingers. Before the birth of the child they are dense and compact, and sink in water. They are highly vascular, and in the child possess a pink colour. In the adult they are bluish-grey, or slate-coloured, or even mottled with black spots, owing to the formation or deposition of colouring matter in their substance. Their size varies not only with the period of life, but with the degree of inflation with air. Their weight after death also varies, in relation to the amount of blood or mucus they may contain. The average weight of both lungs is about 40 oz., and the right lung is somewhat heavier than the left.

Structure of the Lungs and Brônchi.

The Lung is composed of the ramifications of the bronchial tube, of its terminal apparatus the air-cells or pulmonary vesicles: of the branches of the pulmonary artery, the pulmonary capillaries, and pulmonary veins: of the ramifications of the bronchial artery and vein: of nerves and lymphatics. These several structures are bound together by connective tissue, and the entire organ is invested by the pulmonic pleura.

The *pulmonic pleura* forms the external or serous coat of the lung. It closely envelopes the lobes of the lung, and gives to them a smooth, glistening surface. The free surface of the pulmonic pleura is covered by a single layer of endothelial cells. Klein has pointed out that whilst the endothelium covering the costal pleura consists of polygonal scales, like those of serous membranes generally, the cells of the pulmonic pleura are flattened only during inspiration: during expiration, again, they are polyhedral, or even columnar, their contents are distinctly granular, and the nucleus is more spherical in shape. The sub-endothelial tissue of the pulmonic pleura consists of bundles of white fibrous connective tissue intermingled with elastic fibres. Klein has shown that in some animals, more especially the guinea pig, bundles of non-striped muscular fibres form a network immediately beneath the sub-endothelial connective tissue.

Lobules of the Lung.—The pulmonic pleura is so translucent that the surface of the lung may be seen through it to be mapped out into multitudes of small polygonal areas,

the *lobules* of the *lung*. These lobules are not limited to the surface, but are found in great numbers throughout its entire substance, where they are so closely packed together that their boundaries are indistinct. The lung may therefore be regarded as built up of many thousands of lobules. In the human foetus, but more readily in foetal sheep and calves, the lobules may be teased asunder without much difficulty, by tearing through the intermediate connective tissue. In the adult lung they are more closely united to-



FIG. 172.—Portion of the Lung of a foetal calf, to show the division into Lobules. At the right border of the figure the individual lobules have been separated from each other. Natural size.

gether, but their boundaries are often rendered distinct by the formation of pigment in the intermediate connective tissue. The lobules are about the size of peas; they are irregularly pear-shaped, the broader end being directed towards the surface of the lung, whilst the narrow end receives a terminal branch from the bronchial tube.

The *connective tissue* of the lung not only separates the lobules from each other, but forms a layer beneath the pulmonic pleura, which is on the one hand continuous with the interlobular connective tissue, and on the other with the sub-endothelial connective tissue of the pleura. Connective tissue also surrounds the bronchus and blood-vessels at the root of the lung, and is prolonged along with the vessels and bronchus, as their tunica adventitia, into the substance of the organ, where it becomes continuous with the interlobular connective tissue. The interlobular

and sub-pleural connective tissue is the seat in the adult lung of the colouring matter, which gives the lung its dark colour. As a lobule of the lung is a miniature lung, it consists of the structures which characterise the lung itself.

The *bronchial tube*, before it enters the lung, resembles in form and structure the trachea. After it has passed in at the root, it immediately begins to divide into smaller bronchi. The process of division and sub-division goes on, usually in a dichotomous manner, as the bronchi extend into the lung substance, until at last minute bronchi are produced, which pass to the lobules of the lung, and are called *lobular bronchial tubes* (fig. 173). A lobular bronchial tube divides within the lobule into two or more terminal branches, which end by dilating into a number of minute chambers, called the *pulmonary vesicles*, *air-vesicles*, *alveoli*, or *air-cells*.

The larger bronchial tubes within the lung correspond generally in their structure to the trachea, though with some modifications in the arrangement of the constituent tissues. The *cartilage* is not in the form of rings, but of irregularly-shaped plates arranged at intervals around the sides of the tube, which is cylindrical in form, and not, like the trachea, flattened posteriorly. These plates diminish in size and frequency in the smaller bronchi, and finally disappear when the bronchi attain a diameter of not more than about $\frac{1}{20}$ th of an inch. The cartilaginous framework in both the bronchi and trachea keeps the air-tube open, and allows the free ingress and egress of air. The *fibro-elastic membrane* connects the cartilaginous plates together ; it diminishes in strength and thickness as it extends into

the smaller bronchi. The *muscular tissue* forms a definite layer of circular fibres around the entire bronchus not only

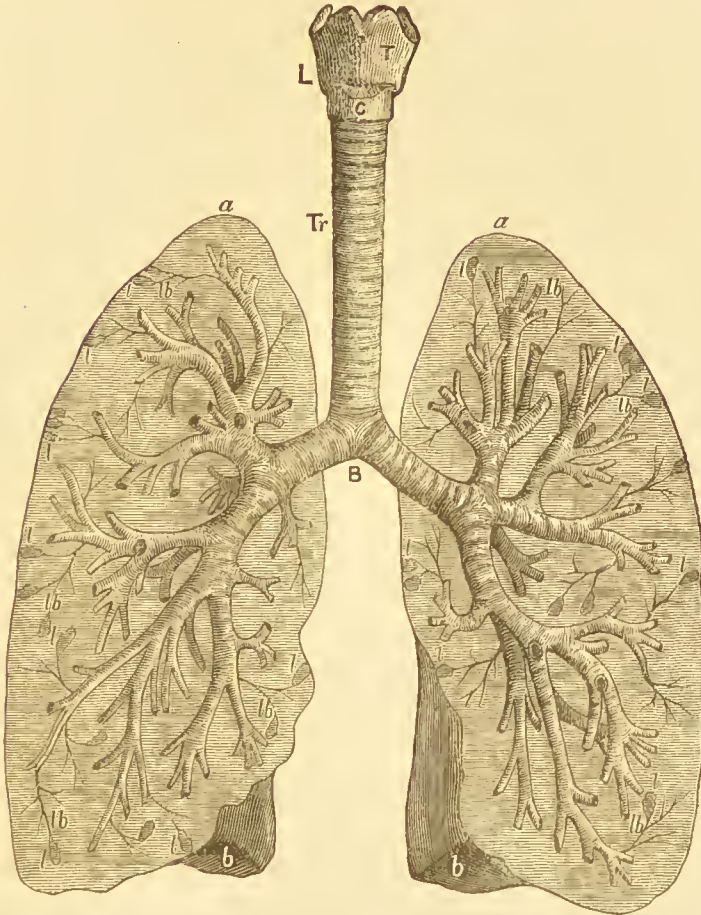


FIG. 173.—The Windpipe and Lungs. L, larynx; T, thyroid cartilage; C, cricoid; Tr, trachea; B, bifurcation into bronchi; a, apex, and b, base of each lung. The ramifications of the bronchi within the lungs are shown; lb lb, lobular bronchial tubes; l, l, l, lobules.

where there are cartilaginous plates, but in the intervals be-

tween them: the muscular layer is between the cartilaginous plates and the mucous membrane: it disappears in the lobular bronchi, where they form the lobular passages. The circular arrangement of the muscular tissue around the wall of the bronchi enables it to constrict these tubes, and modify the ingress of air into, and its egress from the air-vesicles. The *submucous coat* contains longitudinal bundles of elastic tissue continuous with those in the trachea; they diminish in size and distinctness in the smaller bronchi; but elastic tissue can be traced in the walls not only of the terminal branches of the lobular bronchial tubes, but in the walls of the air-vesicles. The presence of longitudinal bundles of elastic tissue in the walls of the bronchi and trachea enables these tubes to be elongated, and to recoil to their former dimensions when the tension is removed. Racemose glands lie outside the muscular layer, between it and the bronchial cartilage: slender ducts proceed from them, which pierce the muscular layer, and open on the free surface of the mucous membrane. Collections of lymphoid tissue are situated in the connective tissue immediately external to the muscular layer. The *mucous membrane* lines the interior of the bronchi. It is covered on its free surface with a layer of ciliated columnar epithelium, amidst which goblet-shaped cells are scattered: the ciliated epithelium disappears in the lobular bronchi, when they begin to form the air-vesicles, and is replaced by a tessellated epithelium.

The *terminal* branches of a lobular bronchial tube lose the cylindrical form of the bronchus, and dilate both laterally and terminally into the *alveoli*, or *air-vesicles*. The collection of air-vesicles surrounding any given terminal bronchus is called a *primary lobule*, or an *infundibulum*

from its funnel-shaped form, whilst the lumen of the terminal bronchus is named the *lobular*, or *alveolar passage*. The relation of the air cells to the lobular passage is not

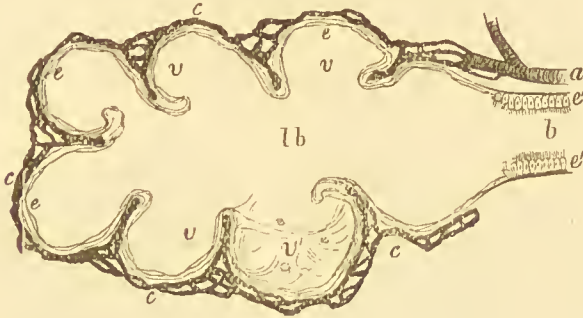


FIG. 174.—Semi-diagrammatic longitudinal section through an Infundibulum. *b*, terminal bronchial tube; *lb*, lobular passage; *vv*, air-vesicles; in *v'* the nucleated elastic membranous wall of a vesicle is shown; *a*, pulmonary artery; *c, c*, pulmonary capillaries; *e'*, ciliated epithelium; *e, e*, tessellated epithelium lining air-cells.

unlike that of a number of small chambers opening into a common corridor. The air-vesicles have an average diameter of about $\frac{1}{100}$ th of an inch, though they not unfrequently are larger in size, and are always bigger at the end than at the commencement of an inspiration. The air-vesicles in the same infundibulum are separated from each other by septa, or partitions, so that they do not communicate directly with each other, but only through the common corridor, or lobular passage: it should be stated, however, that these partitions sometimes break down, and permit contiguous air-vesicles to communicate. The air-cells in adjacent infundibula do not communicate at all, but are separated by a thin layer of intermediate connective tissue, and by the pulmonary capillaries.

The structure of the wall of the air-vesicles and lobular

passages is much more simple than that of the bronchi. It consists of a very thin and delicate fibro-elastic membrane, covered on its free surface by a single layer of pavement epithelium. The epithelial cells are polygonal scales, in contact by their margins, so that they form a continuous layer, which lines not only the bottom of the air-vesicles, but covers the intermediate septa. The nuclei of these

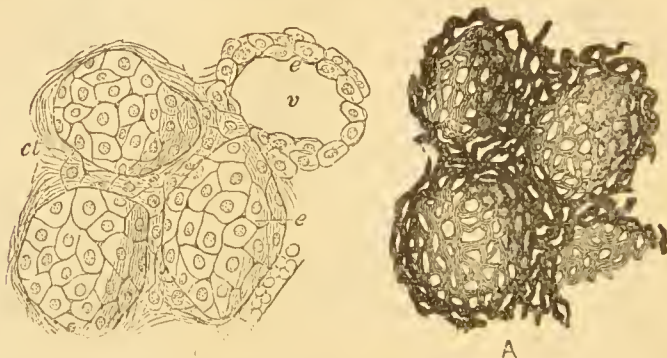


FIG. 175.—A, the pulmonic Capillaries in the walls of the air-vessels; B, the tessellated epithelium *e*, lining the air vesicles of the cat's lung; at *ct*, the elastic fibres in the wall are shown; *c*, a capillary with its blood corpuscles, the size of which may be compared with that of the epithelium cells. $\times 450$.

cells are rounded and granular, so that they are much more easily recognised than the surrounding very translucent protoplasm of the cell substance. This pavement epithelium is in the same morphological plane as the ciliated epithelium of the bronchi. The fibro-elastic membranous wall consists of a very delicate connective tissue in which a few corpuscles are imbedded. Its elastic fibres are distinct, and though few in number at the bottom of an air-vesicle, are more numerous in the intermediate septa, and form apparently a ring-like arrangement around the mouth of the air-vesicle where it communicates with the lobular passage. This elastic tissue permits the air-vesicles to

expand during inspiration, and to recoil during expiration ; but breathing having once begun, the air-vesicles are never empty of air. F. E. Schulze states that the septa between those vesicles, which are next the bronchial tube, contain non-striped muscular tissue, which is absent, however, in the proper walls of the alveoli.

The *pulmonary artery* enters the lung at its root, and



FIG. 176.—The outer surface of two of the Infundibula in a lobule of the lung. B, lobular bronchus; av, air vesicles ; A, pulmonary artery; c, pulmonary capillaries; V, pulmonary vein.

divides and subdivides, without anastomoses, even more frequently than the bronchus, which it closely accompanies. Its finer branches pass to the lobules, along with the lobular bronchi, and within the lobules end in the *pulmonary capillary plexus*. This plexus is dis-

tributed in the fibro-elastic membranous wall of the air-vesicles, passes into the intermediate septa, and forms a ring-like arrangement around the mouths of the air-cells. Its constituent capillaries are very fine, and form an extremely close polygonal meshwork, so that the lung is one of the most vascular of all the organs. The capillaries lie immediately beneath the lining epithelium of the air-vesicles, and are separated by it alone from the air in the air-cells, the anatomical arrangement being such as to facilitate the interchange of gases between the air and the blood; by which the impure venous blood of the pulmonary artery is converted into pure arterial blood, in which state it flows into the pulmonary veins back to the left side of the heart.

The *pulmonary veins* arise in great part by small rootlets from the pulmonary capillary plexus. The rootlets from adjacent pulmonary infundibula, and lobules unite to form larger veins, which accompany the pulmonary artery and leave the lung at the root as two large venous trunks. To some extent also the rootlets of the pulmonary veins arise from a capillary plexus in the walls of the finer bronchi derived from the bronchial artery. The most superficial twigs of the pulmonary veins, which arise from the capillary plexus on the air-vesicles near the surface of the lung, ramify for some distance in the sub-serous connective tissue, when they either join the pulmonary vein at the root of the lung, or sink into its substance to open into some of the more deeply placed pulmonary veins.

The *bronchial* or *nutrient artery* of the lung arises either from the thoracic aorta, or from an intercostal artery, and enters the lung along with the bronchial tube. It is in

part distributed to the lymphatic glands, connective tissue, and the walls of the great vessels at the root of the lung: in part it accompanies the bronchial tube, and breaks up into small arteries, which end in a capillary plexus for the supply of the bronchial mucous membrane and the racemose glands connected with it; in part it is distributed to the interlobular and sub-serous connective tissue. The capillaries which supply the finer bronchi communicate with the pulmonary capillary plexus, and with some rootlets of the pulmonary vein, so that this plexus and the pulmonary veins can be injected from the bronchial artery.

Some years ago I injected a *supplementary* set of *nutrient arteries* for the lungs, consisting of fine branches of the internal mammary and intercostal arteries, which formed an extra-pleural plexus under the mediastinal pleura, and then passed to the lung, both in front of and behind the root, as well as between the folds of the ligamentum latum pulmonis. Having reached the lung, some of these branches entered its substance along with the bronchial tube, whilst others ramified in the sub-serous connective tissue. The extra-pleural plexus keeps up an anastomosis between the arteries of the lung and those of the thoracic wall.

The *bronchial vein* is situated at the root of the lung, and receives venules corresponding to branches of the bronchial artery distributed to both the superficial and deep parts of the lung. It does not, however, convey all the blood which the bronchial artery has carried into the lung, as that artery also communicates through its capillaries with the pulmonary veins. The *lymphatics* of the lung are arranged in a superficial and deep set. The

superficial, or *sub-pleural* lymphatics, form a network beneath the pleural membrane, and communicate, as Klein has shown, with the pleural cavity through microscopic stomata between the endothelial cells. The deep lymphatics arise, according to Klein, in two localities. First, from the walls of the air-cells by means of irregular lacunæ and anastomosing canals, which give origin to lymphatic vessels, that accompany the pulmonary artery and vein, and have been called *perivascular* lymphatics. Second, from the walls of the bronchi by irregular lacunæ and anastomosing canals, situated both in the mucosa and tunica adventitia of the air-tube: they give origin to lymphatic vessels, and form a network in the adventitia of the bronchi, which Klein has named the *peribronchial* lymphatics. The superficial and deep lymphatics enter the bronchial glands at the root of the lung.

The *nerves* of the lung are derived from the pneumogastric and sympathetic branches, from which form at the root of the lung the anterior and posterior pulmonic plexuses, from which fine nerves pass into the substance of the organ with the bronchus, and branch and are distributed along with it. Remak and Julius Arnold have both described minute ganglia on the course of these nerves; and W. Stirling has recently shown that microscopic ganglia are situated on the finer branches of the nerves which lie in the walls of the bronchial tubes.

CHAPTER X.

ORGANS OF DIGESTION.

THE Organs of Digestion, Digestive Apparatus or Chylopoietic Viscera, are situated in the axial part of the body. They are for the purpose of receiving the food, or aliment, of converting that portion of the food, which is digestible, into chyle, so that it may be absorbed and applied to the nourishment of the body ; and of transmitting that which is indigestible onwards to be excreted. The digestive organs consist of an elongated tube, the Alimentary Canal ; of numerous Glands, which pour their secretions into the alimentary canal ; and of a hard masticatory apparatus, the Teeth.

ALIMENTARY CANAL.

The Alimentary Canal is a tube about 28 feet long, which traverses almost the entire length of the axial part of the body. In man and all other vertebrates, it lies in relation to the ventral surface of the bodies of the vertebræ. It commences on the face at the orifice of the mouth, and terminates on the surface of the lower part of the trunk at the orifice of the anus. It is divided into

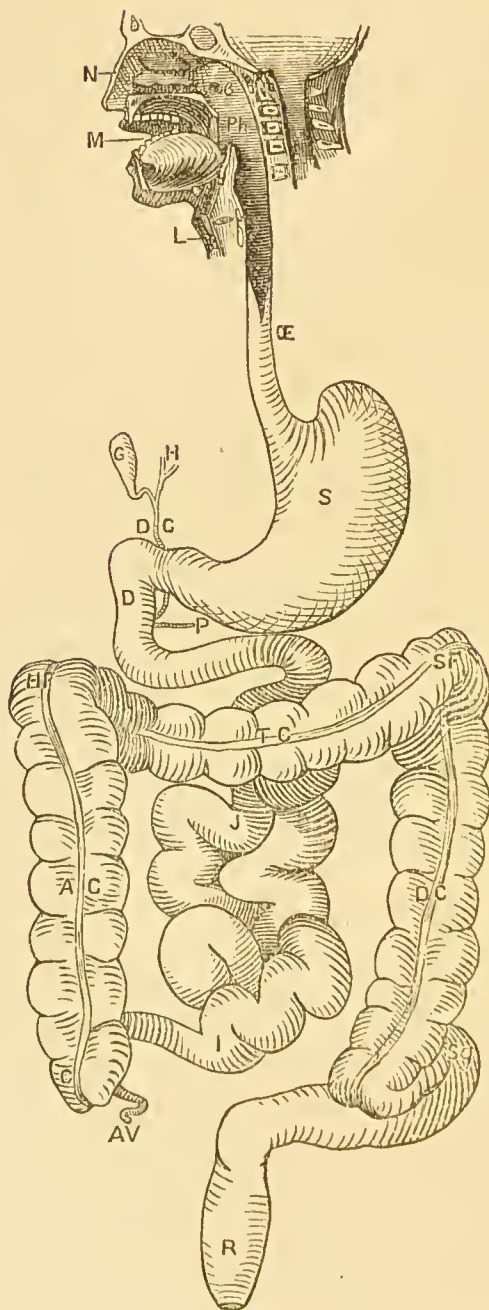


FIG. 177.—Diagram of the several Divisions of the Alimentary Canal. M, mouth; Ph, pharynx; Æ, œsophagus; S, stomach; D, duodenum; J, jejunum; I, ileum; AV, appendix vermiformis; AC, ascending colon; HF, hepatic flexure; TC, transverse colon; SF, splenic flexure; DC, descending colon; Sg, sigmoid flexure; R, rectum; L, larynx; e, Eustachian tube; G, gall bladder; H, hepatic duct; DC, common bile duct; P, pancreatic duct.

a series of segments, or compartments, which communicate with each other, from above downwards, in the longitudinal axis of the canal. These compartments are named mouth, pharynx, œsophagus, stomach, small intestine (subdivided into duodenum, jejunum, and ileum), and large intestine (subdivided into cœcum, colon, and rectum). The canal is lined by a mucous membrane, called the alimentary mucous membrane, which is continuous with the nasal mucous membrane, with the respiratory mucous membrane, and at the anal and oral orifices with the integument. Outside this mucous membrane is the submucous coat, and external to it is the muscular wall of the canal. By the contraction of the muscular wall the food is propelled along the canal from above downwards. Opening on the surface of the mucous membrane are the orifices of the ducts of numerous glands, the secretions of which mingling with the food, act chemically on it, so as to render it soluble and capable of being absorbed.

THE MOUTH.

The Mouth, Oral cavity, or Buccal cavity, is the dilated commencement of the alimentary canal, in which the food is masticated and mingled with the secretion of the salivary and mucous glands. It is situated in the face, and extends from the lips in front, to the pharynx behind. It is bounded above by the hard and soft palate, with the uvula; below by the lower jaw, the mucous membrane of the floor of the mouth, and the tongue; on each side by the cheek; and in front by the lips, between which is the aperture of communication with the surface of the face. Behind it freely communicates with the pharynx through the isthmus faucium, posterior buccal, or pharyngo-oral orifice.

The muscles which enter into the formation of the walls of the mouth are situated in the lips, cheeks, floor of the mouth, tongue, and soft palate.

The muscles of the Lips are as follows :—

Orbicularis, or *Sphincter oris*, surrounds the orifice of the mouth, and forms a large part of the muscular substance of the lips. The fasciculi form a series of ellipses, of which those next the margins of the lips are finer and paler than those that lie further from the margins. The fasciculi in the upper lip are prolonged into those in the lower round the corners of the mouth. The outer border of the muscle blends with the other muscles of the lips: in the upper lip this border is attached by a slip to the septal cartilage of the nose, and by two other slips to the incisive fossæ in the upper jaw; in the lower lip it is

attached by two slips to the lower jaw opposite the canine teeth. The sphincter oris approximates the lips and closes the mouth.

Levator communis arises from the upper part of the nasal process of the superior maxilla; it descends by the side of the nose and divides into two slips, the one of which ends in the ala of the nose, the other blends in the upper lip with the orbicularis oris. From its double insertion and action this muscle is often called *levator labii superioris alæque nasi*.

Levator labii superioris proprius arises from the superior maxillary and malar bones, where they form the lower border of the orbit; it descends into the upper lip to blend with its muscular fibres.

Levator anguli oris arises from the canine fossa of the superior maxilla: it passes downwards and outwards to the angle of the mouth to blend with the other muscles situated there.

Zygomaticus minor, a slender muscle, arises from the anterior end of the zygomatic arch: it passes downwards and forwards, and usually joins the levator labii superioris.

Zygomaticus major arises from the zygomatic arch behind the *minor*: it passes downwards and forwards to the angle of the mouth.

Risorius muscle of Santorini consists of scattered fasciculi, which arise from the fascia covering the masseter muscle: it passes transversely inwards to the angle of the mouth, and is often described as a part of the platysma.

Depressor labii inferioris arises from the front of the inferior maxilla between the symphysis and mental fora-

men, ascends to the lower lip, and blends with the orbicularis oris. From its four-sided form it is sometimes called the *quadratus menti* muscle.

Depressor anguli oris has a broad origin from the external oblique line of the lower jaw; it ascends to the angle of the mouth, where it blends by a narrow insertion with the other muscles which pass there. From its form it is sometimes called *triangularis oris*.

Levator menti, or *levator labii inferioris*, arises from the incisor fossa of the lower jaw: its fibres radiate downwards and forwards to end in the skin of the chin.

The muscle of the Cheek is the *Buccinator*, a flat four-sided muscle, which arises by its upper and lower borders from the outer surface of the upper and lower jaws, a short distance from the alveolar edge, and by its posterior border, from the pterygo-maxillary ligament. From these lines of origin the fibres pass forwards to the anterior border which blends at the angle of the mouth with the other muscles in that region: to some extent the fibres of the upper part of the muscle go into the lower lip, those of the lower part into the upper lip. The *pterygo-maxillary ligament* is a slender fibrous band which stretches from the internal pterygoid plate of the sphenoid to the back of the mylo-hyoid ridge of the lower jaw: as the buccinator arises from it in front and the superior constrictor of the pharynx behind, it forms the bond of union between the muscles of the pharynx and cheek, and ensures the continuity of the walls of these divisions of the alimentary canal.

The muscles of the Floor of the Mouth are the pair of *Mylo-hyoid* muscles, which are situated immediately

beneath the mucous membrane. Each arises from the mylo-hyoid ridge of the lower jaw : the fibres pass downwards and inwards to be for the most part inserted, along with the opposite muscle, into a tendinous median raphe which extends from the symphysis menti to the body of the hyoid bone ; the most posterior fibres are, however, inserted directly into the body of the hyoid. The name of *diaphragma oris* has been applied to the muscular floor formed by the two mylo-hyoid muscles.

The muscles of the Tongue have been described, as a part of that organ, on p. 376 : those of the Soft Palate will be described on p. 666. The action of the muscles of the mouth has been described on p. 84 *e.s.*

The mouth is lined by a red-coloured mucous membrane, which becomes continuous at the posterior buccal orifice with that of the pharynx, and at the margins of the lips with the skin of the face. The mucous membrane covering the alveolar portions of the jaws, and surrounding the necks of the teeth, is called the *gum*. From the outer surface of each jaw it is reflected to the inner surface of the cheeks and lips. A narrow band passing from the symphysis of the lower jaw to the lower lip is the *frænum labii inferioris*, and a similar band from the upper jaw to the upper lip is the *frænum labii superioris*. From the inner surface of the lower jaw the mucous membrane is reflected to the floor of the mouth, and a broad band, called *frænum linguae*, is prolonged to the middle line of the under surface of the tongue. From the back of the dorsum of the tongue three slender folds of the mucous membrane, the *fræna epiglottidis*, are prolonged to the front of the epiglottis. From the soft palate on each side two folds of

mucous membrane proceed; the one extends downwards and forwards as the *anterior pillar of the fauces* to the side of the tongue, and encloses the palato-glossus muscle; the other runs downwards and backwards, as the *posterior pillar of the fauces*, to the wall of the pharynx, and encloses the palato-pharyngeus muscle. In the interval between these pillars is the *tonsil*.

In its structure the mucous lining of the mouth consists of a stratified pavement epithelium, and a sub-epithelial fibro-vascular corium, possessing numerous vascular papillæ. The superficial strata of the epithelium covering the mucous surface of the cheeks and lips are formed of squamous cells, whilst those which lie next the corium are elongated in a direction perpendicular to its surface. Some of the squamous cells have fluted surfaces; others prickle-like edges, by the junction of which adjacent cells anastomose together. From the surface of the corium numerous conical vascular papillæ project into the epithelial layer. At the margin of the lip the mucous membrane becomes continuous with the integument, and the transition from the tegumentary to the mucous surface is marked by the disappearance of the hair follicles and sebaceous glands, by the greater translucency of the epithelial covering and by the greater vascularity of the corium. Klein has described bundles of fibres of the sphincter orbicularis oris muscle passing into the corium of the mucous lining of the lip, as far as the base of the papillæ, and in close proximity to the epithelium.

The mucous membrane of the gum is characterised by its density and toughness, due to the numerous strongly developed bundles of connective tissue in the corium,

many of which are continued into the fibrous tissue of the periosteum, which covers the alveolar surface of the jaw. The free surface of the corium of the gum possesses numerous broad papillæ, and is covered by a stratified pavement epithelium similar to that in the lips and cheeks. The mucous membrane of the hard palate is also tense and tough, though not so much so as the gum; and the fibrous fasciculi of its corium blend with the connective tissue of the subjacent periosteum. The mucous lining of the mouth is a sensitive membrane, and receives its nervous supply from the fifth cranial nerve. The superior maxillary division of that nerve gives branches to the hard and soft palate, upper gum, and mucous lining of the upper lip: the inferior maxillary division to the mucous lining of the cheek and lower lip, lower gum, and floor of the mouth. Krause has described end bulbs, in connection with the terminal branches of the nerves, in the mucous membrane of the lips, floor of the mouth, and soft palate.

The mucous membrane of the mouth is specially modified in some localities by the development of collections of Lymphoid Tissue in the sub-epithelial connective tissue. This is particularly the case in connection with the mucous membrane of the dorsum of the tongue in the interval between the circumvallate papillæ and the epiglottis; and in the substance of the tonsil.

The TONSILS are two almond-shaped bodies, situated, one on each side of the posterior orifice of the mouth, in the fossa between the anterior and posterior pillars of the soft palate. One surface of each tonsil is free, and covered by the epithelium of the mucous membrane; the other is attached to the inner surface of the superior constrictor

muscle of the pharynx. They lie in a plane a little above the angles of the lower jaw. Their normal size is not bigger than a hazel nut, but they are very apt to enlarge, grow inwards across the posterior aperture of the mouth, and diminish the size of that opening. The free surface



FIG. 178.—Vertical section through one of the Tonsils, to show a pit vertically divided. *e*. Its epithelial lining; *f, f*, lymph follicles; *l, l, l*, lymph cells diffused in the connective tissue; *a*, small artery ending in capillary blood-vessels. Slightly magnified.

is marked by several rounded holes, which lead into shallow pits or crypts, which may be either simple or branched, in the substance of the tonsil. The pits are lined by the epithelial covering of the mucous membrane, into which minute papillæ project. In the sub-epithelial connective tissue of the walls of the crypts nume-

rous follicles of lymphoid tissue are situated, and lymph cells are infiltrated in great numbers in the connective tissue between the follicles. Interspersed amidst the crypts are small racemose mucous glands. The tonsils are very vascular, and receive their arteries from the descending palatine branch of the internal maxillary, the ascending pharyngeal of the external carotid, the dorsalis linguae of the lingual, and the tonsillar and ascending palatine branches of the facial. Capillary blood-vessels are distributed in connection with the papillæ, the lymphoid tissue, and the racemose glands. The tonsillar veins form a plexus in relation to the attached surface of the tonsil. Lymph-vessels are found in the tonsils; they form networks

between and around the follicles of lymphoid tissue. Branches of the glosso-pharyngeal nerve, and the descending palatine branches of Meckel's ganglion, pass to the tonsil.

MUCOUS AND SALIVARY GLANDS OF THE MOUTH.

The ducts of numerous glands engaged in secreting mucus and saliva open on the free surface of the mucous membrane of the mouth. Their secretion not only keeps the mouth moist, and aids therefore in articulation, but by mingling with the food assists in mastication, deglutition, and the digestive process. Each gland is characterised by being divided into small lobules, and by possessing a duct or ducts, which branch off in an arborescent manner in the substance of the gland, and finally end in the minute lobules. They all belong to the Compound Racemose group of glands; other examples of which are found in the pancreas, Brunner's glands, the mammæ, the lachrymal glands, Cowper's and Bartholini's glands.

The MUCOUS GLANDS OF THE MOUTH are situated beneath its mucous lining in the following localities:—*a*, *labial* glands in the upper and lower lips, but absent at the angles of the mouth: *b*, *buccal* glands scattered on the inner surface of the cheek from the lips to the opening of the parotid duct: *c*, *palatine* glands on the oral surface of the hard palate, in the uvula, on both surfaces of the soft palate and in the tonsils: *d*, *molar* glands, close to the last lower molar tooth on each side: *e*, *lingual* glands, extending backwards from the tip of the tongue along its margin, and also on the dorsum between the circumvallate papillæ and epiglottis. Blandin and Nuhn

have described a cluster of glands at the tip of the tongue, between the genio-hyo-glossus, stylo-glossus and lingualis, opening by four or five ducts on the under surface of the tip.

Structure.—The ducts of these mucous glands consist of a delicate membrane lined by a single layer of columnar epithelial cells. The terminal branches of the ducts, which enter the lobules, end in a series of saccular dilations, the *acini*, *alveoli*, or *gland vesicles*, which contain rounded or polygonal secreting cells. A collection of such vesicles forms a lobule. The lobules are bound together by intermediate connective tissue, in which the blood-vessels divide into a capillary network, that ramifies on the outer surface of the delicate membrane forming the wall of the gland vesicles.

The SALIVARY GLANDS OF THE MOUTH are the parotid, submaxillary, and sublingual glands.

The *Parotid gland* is the largest salivary gland, and occupies the parotid hollow between the ascending ramus of the lower jaw, the mastoid process of the temporal bone, the external auditory meatus, and the zygoma. Its anterior border overlaps the masseter muscle, and the excretory duct emerges out of this border. A prolongation of gland substance, the *socia parotidis*, frequently accompanies the duct for a short distance. By its deep surface the gland passes as far as the styloid process, the parotid fossa in the temporal bone, the digastric muscle, internal carotid artery, and internal jugular vein. The gland is enclosed in a capsule formed of the cervical fascia. Passing into the gland is the external carotid artery, which gives off in it the occipital, posterior auricular, temporal and

internal maxillary branches: from the posterior auricular and temporal branches arise the small arteries which supply the parotid gland with blood. Emerging from the gland is the external jugular vein, which is formed in it by the junction of the temporal, internal maxillary, posterior auricular and transverse facial veins. Piercing the gland are the facial and auriculo-temporal nerves.

The excretory duct of the gland, called *Stenson's duct*, passes forwards superficial to the masseter muscle, then pierces successively the fat of the cheek, the buccinator muscle and the mucous membrane, and opens on the inner surface of the cheek opposite the second upper molar tooth. The duct is between two and three inches long, and about the thickness of a crow quill.

The *Submaxillary gland* is situated in the submaxillary triangular space, and rests against a shallow fossa on the under surface of the horizontal ramus of the lower jaw. It lies for the most part on the mylo-hyoid muscle, but sends a process, along with the excretory duct, round the posterior border of the muscle, which process lies between the mylo-hyoid and the hyo-glossus muscles. The gland is enclosed in a capsule formed of the cervical fascia, and is separated from the parotid gland by a deep process of that fascia named the stylo-maxillary ligament. The facial artery, as it ascends to the face, passes through the substance of the gland and gives off glandular branches to supply it with blood.

The excretory duct of the gland, called *Wharton's duct*, runs forwards for two inches between the mylo-hyoid and the hyo-glossus and genio-hyo-glossus muscles, and ends by opening on the floor of the mouth by the side of the frænum linguæ.

The *Sublingual* is the smallest of the salivary glands, and lies under the mucous membrane of the floor of the mouth, close to the genio-hyo-glossus muscle and the line of attachment of the frænum linguæ. It is concealed by the mylo-hyoid muscle, and receives, as its arteries of supply, the sublingual branch of the lingual artery and small branches of the submental branch of the facial artery. Instead of having, like the parotid or the submaxillary gland, only a single excretory duct, it possesses from ten to twenty small ducts, the *ducts of Rivinus*, some of which join Wharton's duct, though the greater number open directly into the floor of the mouth near the frænum linguæ.

Structure.—The ducts of the salivary glands branch and terminate in the lobules; each terminal duct ending in a series of saccular dilatations, the *acini*, *alveoli*, or *gland-vesicles*, the wall of which, formed apparently of a membrana propria, is continuous with the simple membranous wall of the terminal duct. The terminal ducts are lined by a layer of squamous epithelium. The wall of the larger ducts is formed of white and yellow fibrous tissue, with, in some instances, contractile muscular fibre-cells, and is lined by a columnar epithelium.

The gland vesicles contain the secreting cells, which present two different histological appearances. The cells which lie in the centre of the alveolus approach the spheroidal in form, though with the sides often flattened; their protoplasm is granulated, though it may clear up, apparently from a mucous change in its substance; their nucleus is distinct, and usually close to the circumference of the cell. The cells which lie next the wall of the vesicle are smaller, with a more granulated protoplasm, and on

section present a semilunar form ; they were first described by Gianuzzi as the semilunar body. Lavdowsky states that the semilunar cells are connected together by a network of exceedingly delicate threads of protoplasm. Though some have supposed these two forms of cells to be quite distinct, it is not improbable that the peripheral, so-called semilunar cells are merely a younger stage of the central secreting cells, which have not yet undergone a mucous change. Both kinds of cells are found in the submaxillary and sublingual glands ; but in the parotid, the secreting cells exhibit a uniform granulated protoplasm, and do not undergo the mucous change. Heidenhain has pointed out that, when the submaxillary gland has been stimulated for some time, the central cells lose their clear transparent appearance, and assume the characters of a granulated protoplasm, a change which is doubtless due to the contained "mucus" being poured out in the secretion. Boll has described the membrana propria of the gland-vesicles as consisting of anastomosing connective tissue cells, and an anastomosing reticulum of connective tissue corpuscles has been said to exist between the cells situated within the vesicles. Pflüger has described minute channels, or intercellular passages between the secreting cells, which communicate with the lumen of the duct, and serve as the passages along which the salivary secretion flows out of the vesicle. Schlüter and Pflüger have described smooth muscular fibre-cells, arranged either solitarily, or in fasciculi, in the connective tissue framework of the salivary glands.

The blood-vessels are distributed in the interlobular connective tissue, and form a capillary network on the wall of the gland-ducts, and on the wall of the gland vesicles.

Gianuzzi has described lymphatics, in the interlobular connective tissue, and around the arteries and veins of the glands. The submaxillary and sublingual glands receive their nervous supply from the chorda tympani branch of the facial nerve, and from the third division of the fifth cranial and sympathetic through the submaxillary ganglion. The parotid gland is supplied by the small superficial petrosal branch of the facial and by the sympathetic. The nerves pass into the interlobular connective tissue, branch in their course, and sometimes are connected to minute ganglia. Pflüger states that medullated fibres can be traced up to the gland vesicles, where they perforate the membrana propria, and then lose the medullary sheath, whilst the axial cylinder is prolonged into the protoplasm of the secreting cells. Other medullated fibres, he says, pierce the walls, of the gland ducts, and after losing their medullary sheath, the axial cylinders branch, and become continuous with the columnar epithelial lining of the duct. He has also described multipolar cells, which he believes to be nervous, directly continuous by their processes with the secreting cells. Pflüger's observations, however, on the direct continuity of the nerve fibres and cells with the secreting cells of the salivary glands have not been generally accepted.

THE PHARYNX.

The Pharynx is an irregularly dilated canal, which forms a common passage, connecting the mouth with the œsophagus, and the nose with the larynx, so as to be subservient to the processes both of deglutition and respiration. It is situated in the upper part of the neck, and extends from the basi-cranial axis, which forms its upper boundary, as low down as the level of the sixth cervical vertebra, where it becomes continuous with the œsophagus. It lies in front of the six upper cervical vertebrae, with their prevertebral muscles, from which it is separated by some loose areolar tissue. It is placed behind the nose, mouth, and larynx, all of which communicate with it through openings in its anterior wall. Its length is from $4\frac{1}{2}$ to $5\frac{1}{2}$ inches; the transverse diameter is greater than the antero-posterior, and it is wider opposite the back of the mouth and the great cornua of the hyoid bone, than opposite the back of the nose, or larynx; at its lower end it assumes a tubular form, where it becomes continuous with the œsophagus. Its walls are composed of muscles and membrane, which are arranged so as completely to wall in the tube laterally and posteriorly, but to permit of free communication in front with the nose, mouth, and larynx. If the pharynx be opened by a longitudinal incision through the posterior wall, two structures, viz., the soft palate and epiglottis, will be seen to project into it from the anterior wall. The soft palate, with the uvula depending from its lower border, inclines downwards and backwards, and divides the upper or nasal part of the pharynx from the

middle or buccal portion. The epiglottis projects upwards immediately in front of the orifice of the larynx, and marks the boundary between the buccal part of the pharynx and the superior orifice of the larynx.

Seven openings communicate with the interior of the pharynx (fig. 181). Into the upper or nasal portion are the two posterior nares, separated from each other by the posterior edge of the nasal septum; and the trumpet-shaped mouths of the two Eustachian tubes open, one on each side, in line with the posterior end of the inferior turbinated bone of the same side. Below the soft palate is the posterior orifice of the mouth; behind the epiglottis is the superior aperture of the larynx; opposite the sixth cervical vertebra the pharynx communicates with the œsophagus.

Structure.—The wall of the pharynx consists of three coats, an external muscular, an internal mucous coat, and an intermediate fibrous membrane, which blends with the submucous coat.

The *muscular coat* consists of three pairs of circularly arranged muscles, the constrictors of the pharynx; and of two pairs of longitudinally-arranged muscles, the stylo-pharyngei and palato-pharyngei, with occasionally a third pair, the salpingo-pharyngei. The constrictor muscles extend from the lateral wall to the middle line of the posterior wall of the pharynx, and are named from below upwards the inferior, middle, and superior constrictors; they lie on three different planes, so that the inferior constrictor overlaps the middle, and the middle the superior.

Inferior constrictor, or *laryngo-pharyngeus* muscle, arises from the side of the cricoid cartilage of the larynx,

from the oblique ridge on the outer surface, and the upper and lower borders of the lateral plate of the

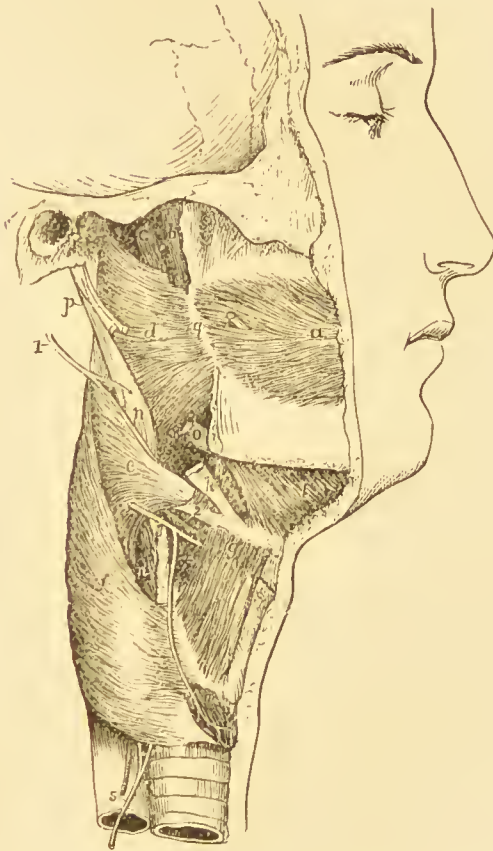


FIG. 179.—Profile view of Cheek and Pharynx showing the Constrictor Muscles. *a*, buccinator; *b*, tensor; *c*, levator palati; *d*, *e*, *f*, superior, middle, and inferior constrictors; *g*, thyro-hyoid; *h*, hyo-glossus; *i*, mylo-hyoid; *m*, crico-thyroid; *n*, stylo-pharyngeus; *o*, stylo-glossus; *g*, pterygo-maxillary ligament which gives origin to buccinator and superior constrictor; 1, glosso-pharyngeal nerve; 2, superior laryngeal artery; 3, superior laryngeal nerve; 4, external laryngeal branch to crico-thyroid muscle; 5, inferior laryngeal nerve and artery.

thyroid cartilage; its fibres curve backwards, to be inserted into the middle line of the posterior surface of the pharynx,

where it joins its fellow of the opposite side. Its lower fibres are in relation to the upper fibres of the œsophagus.

Middle constrictor, or *hyo-pharyngeus* muscle, arises from the great and small cornua of the hyoid bone and from the stylo-hyoid ligament; its fibres radiate in a fan-shaped manner, and curve backwards to be inserted into the middle line of the posterior surface of the pharynx, where it joins its fellow.

Superior constrictor, or *gnatho-pharyngeus* muscle, arises from the side of the tongue and adjacent buccal mucous membrane, from the back of the mylo-hyoid ridge of the lower jaw, from the pterygo-maxillary ligament, and the lower third of the posterior border of the internal pterygoid plate of the sphenoid; its fibres curve backwards to be inserted into the middle line of the posterior surface of the pharynx, where it joins its fellow; but the highest fibres are inserted into the pharyngeal tubercle on the under surface of the basi-occipital. The upper border forms a concave curve from the origin to the insertion, and the fibrous tunica pharyngis interna fills up the interval between it and the basis-cranii.

Stylo-pharyngeus muscle arises from the root of the styloid process: its fibres run obliquely downwards and inwards, between the superior and middle constrictors, to be inserted partly into the posterior border of the thyroid cartilage, and partly to blend with the adjacent part of the muscular wall of the pharynx.

Palato-pharyngeus muscle arises in the soft palate, where it decussates across the mesial plane with the corresponding muscle of the opposite side: its fibres pass downwards in the posterior pillar of the fauces, and spread

out in the muscular wall of the pharynx from the posterior border of the thyroid cartilage, back to and even across the middle line of the pharynx posteriorly.

Salpingo-pharyngeus muscle, when present, arises from the cartilage of the Eustachian tube; its fibres descend in the postero-lateral wall of the pharynx, to be inserted along with the palato-pharyngeus.

The muscular wall of the pharynx is enveloped by a fibrous membrane, the *tunica pharyngis externa*, which is continuous superiorly with the fibrous membrane covering the buccinator muscles. Between the muscular and mucous coats of the pharynx is the *tunica pharyngis interna*, which forms in the posterior wall of the nasal part of the pharynx a well-defined fibrous membrane. It is attached above to the petrous-temporal, the basi-sphenoid, and the pharyngeal tubercle of the basi-occipital. From this tubercle a slender band passes longitudinally down the middle line of the posterior wall of the pharynx and forms a common insertion for the three pairs of constrictors. As the tunica interna descends in the wall of the pharynx it becomes thinner, and is finally lost in the submucous coat.

The *mucous coat* of the pharynx lines the canal, and is continuous through the several openings with the mucous membrane lining the Eustachian tubes, nose, mouth, larynx, and œsophagus.

The epithelium covering the mucous membrane of the nasal part of the pharynx is columnar and ciliated over a considerable surface, but elsewhere the pharyngeal epithelium is tessellated and stratified; and in the latter localities, vascular papillæ project into the epithelial

layers. Small racemose glands, similar to the mucous glands of the mouth, or to Brunner's glands, lie beneath the mucous membrane, which is pierced by their ducts to open on the surface (fig. 180): they are most numerous



FIG. 180.—Vertical section through the mucous membrane of the Pharynx to show the racemose glands. *e*, the epithelium; *ct*, subjacent connective tissue; *g*, racemose gland; *d*, its duct; *a*, artery ending in a capillary plexus on the gland vesicles. $\times 40$.

in the nasal part of the pharynx. Collections of lymphoid tissue are found in the sub-epithelial connective tissue, more especially in the nasal part of the pharynx, where it forms a mass, extending across the posterior and upper wall, between the openings of the two Eustachian tubes, which Luschka has called the *pharyngeal tonsil*. A network of lymphatic vessels exists both in the submucous coat, where it lies in relation to the lymphoid tissue, and between the tunica pharyngis externa and muscular coat; lymphatic glands are in connection with the latter part of the network. The arteries of the pharynx are derived

from the ascending pharyngeal branch of the external carotid, the ascending palatine and tonsillar of the facial, and the palato-pharyngeal and descending palatine branches of the internal maxillary. The motor nerves of the pharynx are derived from the pharyngeal branches of the vagus, the external laryngeal nerve and the glosso-pharyngeal nerve. The sensory nerves arise from the pharyngeal branches of the glosso-pharyngeal, and from the pharyngeal branch of Meckel's ganglion, which latter supplies the mucous lining of the nasal part of the pharynx. Sympathetic nerve fibres pass to the pharynx from the superior cervical ganglion. The motor, sensory, and sympathetic nerves unite to form the pharyngeal plexus situated behind the middle constrictor muscle.

The SOFT PALATE forms an inclined plane, which projects, downwards and backwards into the pharynx, from the posterior border of the hard palate. It is less dependent at the sides than in the mesial plane, where it forms an elongated body, the *uvula*. From its position it is in relation both to the mouth and the pharynx. Its anterior or oral surface is smooth, and gives origin on each side to a fold, which curves downwards to the side of the root of the tongue, to form the *anterior pillars of the palate or fauces*. Its posterior or pharyngeal surface, also smooth, gives origin on each side to a fold, which, springing from the base of the uvula, curves downwards and backwards to be lost in the side walls of the pharynx; this pair of folds forms the *posterior pillars of the palate or fauces*.

Structure.—The soft palate is complex in structure, and consists of muscles, mucous membrane, glands, blood and lymph vessels, and nerves. The muscles of the soft

palate are arranged in two groups, those which elevate and make it tense, and those which constrict the fauces.

The tensors and elevators are as follows:—

Levator palati arises from the front of the under surface

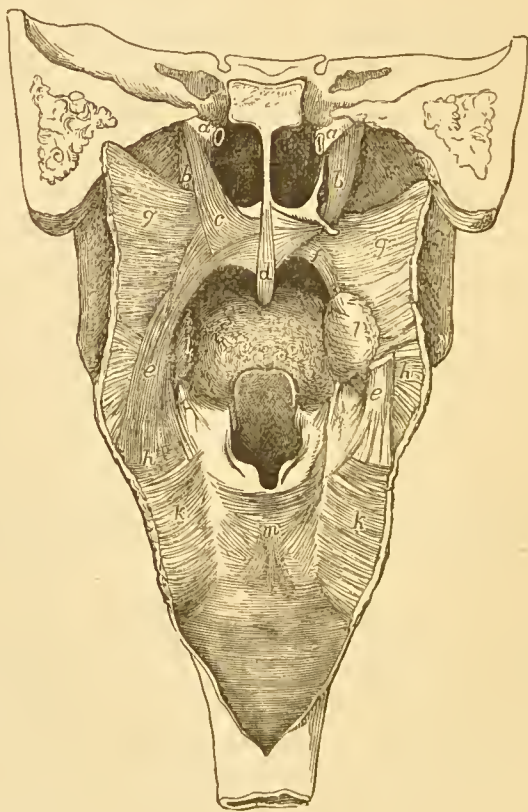


FIG. 181.—Interior of the Pharynx exposed by cutting through its posterior wall. The mucous membrane has been removed, and the muscles of the Soft Palate are exposed. *a, a*, Eustachian tube; *b, b*, tensor; *c*, levator palati; *d*, levatores or azygos uvulae; *e, e*, palato-pharyngeus, cut through on the right side to show, *l*, the tonsil, and *f*, the palato-glossus; *g, h, k*, the three constrictors.

of the petrous temporal, and from the membrano-cartilaginous wall of the Eustachian tube: it passes through the wall of the pharynx above the upper concave border of the superior

constrictor, and enters the soft palate in the posterior part, in which it may be traced up to the mesial plane.

Levatores or *Azygos uvulæ* consist of two fasciculi, one on each side of the mesial plane of the uvula, which arise from the spine of the palate plates of the palate bones, and descend into the uvula towards its tip.

Tensor or *Circumflexus palati* arises from the scaphoid fossa at the root of the internal pterygoid plate, and from the outer third of the wall of the Eustachian tube: it descends in the pterygoid fossa, and ends in a tendon which hooks round the root of the hamular process, and pierces the wall of the pharynx between the pterygoid and pterygo-maxillary origins of the superior constrictor; it enters the soft palate and expands into an aponeurotic tendon, which blends in the mesial plane with that of the corresponding muscle, and is attached to the under surface of the palate plate of the palate bone.

The constrictors of the fauces are as follows:—

Palato-glossus forms, along with its fellow, a sphincter arrangement in the soft palate, anterior palatine pillars and tongue. It lies in the soft palate in close relation to the mucous membrane of the anterior surface, descends in the anterior pillars to the sides of the root of the tongue, into the substance of which it enters. By its contraction it constricts the pharyngo-oral orifice.

Palato-pharyngeus has been described on p. 662.

The action of the muscles of the soft palate and pharynx in connection with the process of deglutition has been described on p. 88. From their attachment to the wall of the Eustachian tube, the tensor and levator palati muscles can, when the soft palate is fixed, act on the tube. The

tensor palati is believed to be a dilator of the tube. The levator palati is also regarded by some as a dilator, but Cleland maintains that it acts as a constrictor by approximating the membranous to the cartilaginous wall of the tube.

The mucous membrane of the soft palate is continuous with that of the mouth and pharynx. The epithelium covering the anterior or oral surface is a stratified pavement epithelium. That on the posterior or pharyngeal surface appears to vary at different periods of life; for whilst Klein found in the infant a laminated cylindrical and ciliated epithelium, with isolated areas of pavement epithelium, in adults the surface generally was covered by a laminated pavement epithelium. Numerous racemose mucous glands lie beneath the mucous membrane, but much more abundantly on the oral than on the pharyngeal aspect. Collections of lymphoid tissue, similar to those found in the tonsils, are also met with. The arteries are the descending palatine branches of the internal maxillary, the inferior palatine of the facial, and palatine branches of the ascending pharyngeal. The veins of the soft palate often assume a dilated character, and are continuous with the pharyngeal veins. Lymphatics are also distributed beneath the mucous membrane.

There are difficulties in determining with precision the motor nerves of the soft palate. A branch from the otic ganglion of the third division of the fifth nerve passes to the tensor palati. The levator palati and azygos uvulae are by some considered to be supplied by the pharyngeal branches of the vagus, though others regard them as supplied by the large superficial petrosal of the facial,

which goes to Meckel's ganglion, and sends branches to the palate in the descending palatine branches of that ganglion. The palato-pharyngeus and palato-glossus are probably supplied by the pharyngeal branches of the vagus. The sensory nerves to the mucous membrane are derived, from the second division of the fifth, through the descending palatine branches of Meckel's ganglion. Sympathetic nerve fibres also probably accompany the descending palatine nerves.

ŒSOPHAGUS.

The Œsophagus, or Gullet, is an almost cylindrical tube, about 9 or 10 inches long, which transmits the food from the pharynx to the stomach. It commences in the neck opposite the body of the sixth cervical vertebra, where it is continuous with the pharynx. It passes down the lower part of the neck, traverses the cavity of the thorax, pierces the diaphragm at the œsophageal opening, enters the abdomen, and becomes continuous with the cardiac end of the stomach close to that opening. It lies in front of the bodies of the vertebræ, and follows the antero-posterior curvatures of the spine, but, at the lower part, both of the neck and thorax, it inclines somewhat to the left of the mesial plane. It is placed behind the trachea, the arch of the aorta, the heart, and pericardium. In the thorax it is situated in the posterior mediastinal division of the interpleural space, with the vena azygos to its right, and the descending aorta at first to its left and then behind it. It is closely accompanied in the greater part of its course by the pneumogastric nerves, which form a plexus around it.

Structure.—The wall of the œsophagus consists of three

coats, named, from without inwards, muscular, sub-mucous, and mucous coats.

The *muscular* or *external coat* is divided into two layers, an external and an internal. The *external* layer is composed of fibres arranged *longitudinally* in the wall. They are collected into three bundles; one springs from the back of the cricoid cartilage and descends in the anterior wall, the others are situated at the sides of the œsophagus; as they reach its lower end the fibres are no longer collected into three bundles, but form a uniform layer around the tube. The *internal* layer consists of fibres arranged in a series of rings around the tube, which lie sometimes horizontally, at others obliquely. The muscular coat in the upper fourth of the œsophagus is red, and its fibres are transversely striped; in the second fourth numerous non-striped fibres are mingled with the striped; whilst in the lower half the coat consists exclusively of non-striped fibres. By the contraction of the fibres of the muscular coat the food is propelled downwards into the stomach. Hyrtl described in 1844 muscular slips as occasionally found passing from the œsophagus to the pleura and left bronchus. D. J. Cunningham, who has recently examined this arrangement, states that the *pleuro-œsophageal muscle* arises from the left pleura, where it lies over the thoracic aorta, and joins the left margin of the œsophagus; it is always present. The *broncho-œsophageal* muscle is not so constant; it springs from the back of the left bronchus, and blends with the longitudinal fibres of the œsophagus.

The *sub-mucous coat* connects the muscular and mucous coats with each other. It consists of bundles of white fibrous tissue intermingled with elastic fibres, and the

nerves and blood-vessels passing to the mucous coat ramify in it.

The *mucous* or *internal coat* lines the interior of the tube, is continuous above with the mucous lining of the pharynx, and below with that of the stomach. When the œsophagus is empty it is thrown into longitudinal folds. Its free surface is covered by a thick layer of stratified squamous epithelium, which terminates abruptly at the cardiac orifice of the stomach in an irregular line. Projecting into the epithelium are multitudes of minute conical papillæ. Opening on the surface of the membrane are the ducts of numerous small racemose glands similar to those in the pharynx (fig. 180). Collections of lymphoid tissue, forming solitary follicles, are also found in the mucous membrane. The deep surface of the mucous membrane consists of a layer of non-striped muscular tissue, the bundles of which run longitudinally; it forms the muscular layer of the mucous coat, or *muscularis mucosæ*.

The œsophagus is supplied with blood by the inferior thyroid artery, the œsophageal branches of the thoracic aorta and the ascending branch of the coronary artery of the stomach. The nerves are derived from the pneumogastrics, which form plexuses containing nerve cells, not only in the muscular coat, but in the *muscularis mucosæ*. A network of lymphatic vessels also occurs in both the mucous and sub-mucous coats.

ABDOMINAL CAVITY AND PERITONEUM.

As the remaining portions of the Alimentary Canal are situated in the Abdominal Cavity, it will be advisable, before describing their anatomy, to give an account of the form and boundaries of that cavity, of its division into regions, and of the general arrangement of the peritoneum, which constitutes its lining membrane.

The ABDOMINAL CAVITY, ABDOMEN, or BELLY, is the largest of the three great cavities of the body. It occupies about the lower two-thirds of the trunk, and extends from the diaphragm above to the pelvic floor below. As its walls, except in the pelvic region, are chiefly formed of muscles and of fibrous membrane, they are much more distensible than those of the thorax, and permit considerable modifications in the size of the viscera, contained within the cavity, to occur.

The abdomen is elongated in form: its vertical diameter is greater than either the transverse or the antero-posterior diameter. The superior boundary is formed by the concave vault of the diaphragm, and by the seven lower pairs of ribs and costal cartilages: in this boundary occur the opening through which the œsophagus passes into the abdomen; also the apertures for the transmission of the great blood-vessels, the nerves and the thoracic duct. The inferior boundary is formed by the levatores ani and coccygei muscles, and the pelvic fascia: in relation to this boundary are the termination of the rectum and anal orifice, the termination of the urethra, and in the female that of the vagina also. The anterior boundary is formed above by the muscles of the anterior abdominal wall and

the fascia transversalis: the linea alba occupies its middle line, and about the middle of the linea alba is the umbilicus or navel: the anterior wall below is formed by the two pubic bones with the symphysis. The lateral walls, or flanks, are formed above by the flat muscles of the abdominal wall and the fascia transversalis, and below on each side by the ilium and ischium with the muscles attached to them. The posterior wall is formed by the lumbar spine, sacrum, and coccyx, and by the muscles attached to these bones with their accompanying fasciæ.

The abdomen is primarily divided into the *pelvis* and *abdomen proper*. The *pelvis* is subdivided into the *false pelvis*, or part above the pelvic brim, and *true pelvis*, or part below the pelvic brim.

The *abdomen proper* is subdivided into nine regions, the boundaries of which are not regulated by anatomical structures, but by certain lines drawn upon the surface of the body, which are supposed to be prolonged through the cavity in imaginary planes. An upper horizontal line is drawn on a level with the most prominent part of the ninth pair of costal cartilages, and a lower horizontal line on a level with the summit of the iliac crest. Through these lines the abdomen is divided into three zones, an upper or *costal*, a middle or *lumbar*, a lower or *iliac*. Each of these zones is subdivided into three regions by two vertical lines drawn perpendicularly upwards from the middle of Poupart's ligament. The costal zone is subdivided into two lateral regions, the *right* and the *left hypochondrium*, and a middle or *epigastrium*; the epigastrium lies immediately below the xiphi-sternum, in the interval of divergence between the costal cartilages of

opposite sides, and is sometimes called the pit of the stomach; whilst the hypochondriac regions are under cover of the lower ribs and costal cartilages. The lumbar zone is subdivided into two lateral regions, the *right* and the *left lumbar* regions, or the loins, and a middle or *umbilical* region; in the middle of the umbilical region is the navel, which is placed opposite the body of the fourth lumbar vertebra. The iliac zone is subdivided into two lateral regions, the *right* and the *left iliac* regions, and a middle or *hypogastrium*; the hypogastrium is situated immediately above the pubic symphysis and the bodies of the two pubic bones, and opposite the bodies of the sacral vertebræ. The position of the viscera in these regions will be given in the account of their descriptive anatomy.

The PERITONEUM is the largest and most complicated serous membrane in the body. Like the other serous membranes, it not only lines the walls of the cavity in which it is situated, but gives a more or less complete investment to the contained viscera. It is arranged, therefore, so as to form a *parietal* and a *visceral* part, which are continuous with each other in the various regions, where the part lining the wall is reflected as a covering upon the viscera. A space or cavity, called the *peritoneal cavity*, is enclosed between the parietal and visceral layers. This cavity, as in other serous membranes, is a closed or shut sac, without any communication externally, except in the female, where the two Fallopian tubes open into it. Through these openings the mucous membrane lining the tubes becomes continuous with the serous membrane, and a communication is established between the lumen of each tube and the peritoneal cavity. That surface of both the

parietal and visceral portion of the peritoneum, which lies next to the cavity, is free, smooth, covered by an epithelium, and lubricated by a little serous fluid, which under some pathological conditions may be greatly increased in quantity, so as to cause abdominal dropsy. The moistening of the two free surfaces by the serum permits them to glide smoothly on each other, during the movements of the viscera, and the changes which take place in their size and position. The opposite surface of the peritoneum is attached—that of the parietal part to the fasciæ situated internal to the abdominal muscles—that of the visceral part to the subjacent coat of the several organs.

The attached surface of the parietal part is connected to the abdominal fasciæ by areolar tissue, which is usually so loose as to permit the peritoneum to be stripped off without difficulty. In some localities, as the region of the kidneys, the iliac fossæ and the inguinal regions, fatty tissue, often in considerable quantities, is developed external to the peritoneum. To this fat, and the areolar tissue in which it lies, the name of sub-peritoneal fat and areolar tissue is usually applied, but the name *extra-peritoneal* would more appropriately express its position. It is in this fat and areolar tissue that the extra-peritoneal vessels, already referred to (pp. 432, 525), ramify.

The parietal part of the peritoneum is in some localities elevated into folds, or dimpled into fossæ. In the middle of the anterior abdominal wall, is a longitudinal fold extending from the fundus of the bladder to the navel, and marking the position of the obliterated urachus. On each side of, and somewhat removed from, this mesial fold is a lateral fold, also extending towards the navel, and mark-

ing the position of the obliterated hypogastric artery; and outside this again is a slight fold along the course of the deep epigastric artery. Between the urachal and hypogastric folds is a dimple-like fossa: between the hypogastric and epigastric folds is a similar depression. Immediately external to the epigastric fold is a depression corresponding to the internal or deep abdominal ring—the entrance to the inguinal canal. Immediately below the inner end of Poupart's ligament, another depression may sometimes be seen, which marks the crural ring, or entrance into the crural canal. The inguinal and crural fossæ are of great surgical interest in relation to the seats of inguinal and femoral herniæ.

In the posterior abdominal wall, immediately to the left of the junction of the duodenum and jejunum, and on a level with the left side of the 2nd lumbar vertebra, a pocket-like involution of the peritoneum, about the size of a walnut, is sometimes seen. The entrance to this pocket is marked by a crescentic fold of the peritoneum continuous with the meso-colic fold. Coils of the small intestine have been known to become incarcerated in this pocket, a condition which has been named retro-peritoneal hernia, though the name intra-peritoneal, as suggested by J. Chiene, would be more appropriate. A pocket-like involution of the peritoneum sometimes exists behind and below the cœcum; and another in the peritoneal fold at the junction of the sigmoid flexure of the colon with the rectum, both of which may become the seats of an intra-peritoneal hernia.

Special names are applied to the folds or duplicatures of the peritoneum, which pass from the wall of the abdomen

to the viscera. In the case of the liver, spleen, bladder, and uterus, these folds are named *ligaments*, whilst the corresponding folds which pass to the intestine have received the name of *mesenteries*. Folds of peritoneum also pass between certain of the viscera themselves, and these are called *omenta*.

To understand the disposition of the peritoneum in relation to the viscera, it will be necessary to follow it from the wall to the different viscera, and from one viscus to another. If we commence with the roof of the abdomen, we find that the peritoneum is reflected from the under surface of the diaphragm to the liver, to form the *suspensory*, *coronary*, and *lateral ligaments* of that organ; also from the diaphragm to the spleen as its *suspensory ligament*; also from the diaphragm to the stomach at its junction with the œsophagus as the *gastro-phrenic ligament*; also from the diaphragm to the splenic flexure of the colon as the *phrenico-colic ligament*. The liver is invested by the peritoneum, which is reflected from the lips of its transverse fissure to the lesser curvature of the stomach, as the two layers of the *gastro-hepatic* or *small omentum*. The anterior layer of this omentum is prolonged over the anterior surface of the stomach, and the posterior layer over its posterior surface, as far as the greater curvature. Both layers then leave the stomach and form the descending layers of the *great omentum*, which hangs pendulous, like an apron, in front of the coils of the small intestine, and forms a free border below. At its left border the great omentum becomes continuous with the gastro-splenic omentum, and at its right border it reaches the hepatic flexure and upper end of the ascending colon. At the

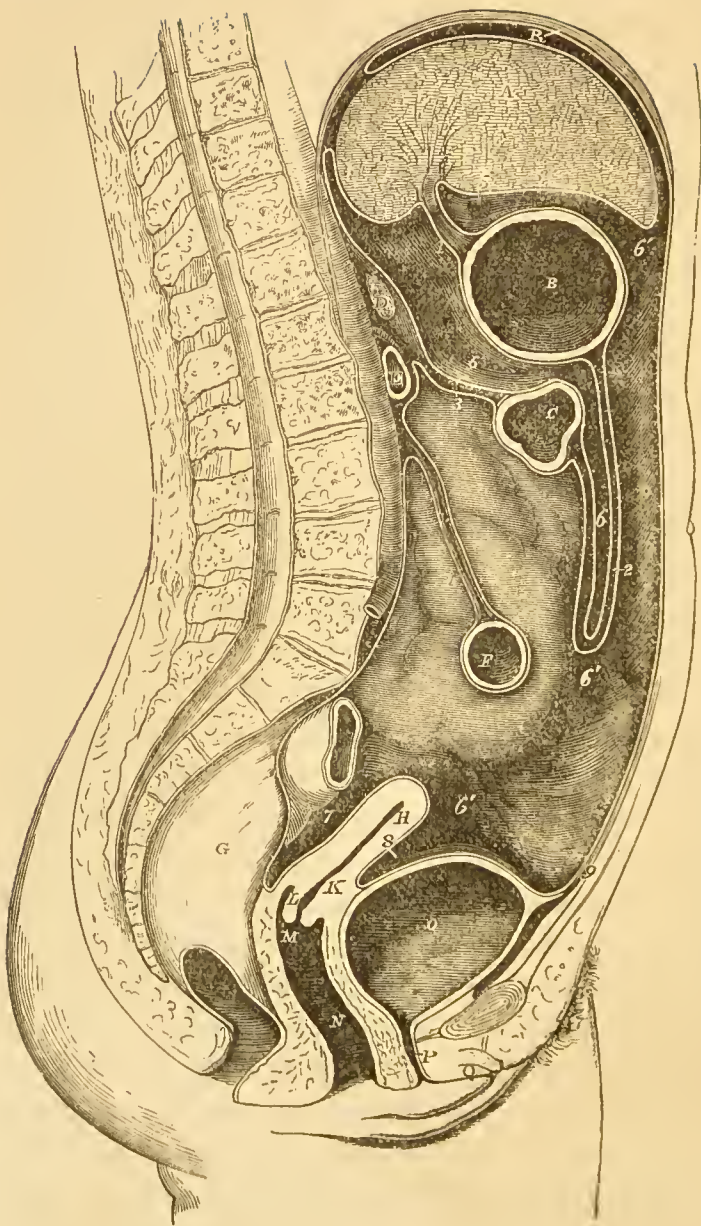


FIG. 182.—Diagram of Peritoneum as displayed in a vertical section through the abdominal cavity and viscera of a female subject. A, liver; B, stomach; C, transverse colon; D, pancreas; E, duodenum; F, ileum; G, rectum; H, uterus; K, cervix uteri; L, posterior lip of os uteri; M, os uteri; N, vagina; O, bladder; P, urethra; Q, clitoris; R, diaphragm; 1, small omentum; 2, great omentum; 3, transverse meso-colon; 4, mesentery; 5 points to foramen of Winslow; 6 6, lesser cavity of peritoneum; 6' 6' 6', greater cavity of peritoneum; 7, recto-vaginal pouch; 8, utero-vesical pouch; 9, parietal layer of peritoneum.

lower free border of the great omentum, these descending layers bend upwards as the ascending layers of the great omentum, and in their ascent meet the transverse colon, when the two ascending layers separate from each other in order to enclose the transverse colon. After enclosing it, they again come together, and pass backwards to the spine as the *transverse meso-colon*.* The two layers of the transverse meso-colon then separate from each other. The one ascends in front of the pancreas to the diaphragm, where it becomes continuous with the posterior layer of the coronary and left lateral ligaments of the liver. The other descends as the *anterior layer* of the *mesentery*, reaches the coils of the jejunum and ileum, is prolonged around the wall of the gut, and then ascends to the spine, as the *posterior layer* of the *mesentery*. The line of attachment of the two layers of the mesentery to the front of the spine is called the *root of the mesentery*. From this line the peritoneum spreads out laterally; on the right side of the abdomen it covers the anterior and lateral surfaces of the cœcum and ascending colon, but not the posterior surface; on the left side of the abdomen it has a similar relation to the descending colon, but it forms a complete investment for the sigmoid flexure of the colon, and is reflected to the left iliac fossa as the *sigmoid meso-colon*.

From the root of the mesentery the posterior layer

* This account of the relation of the omentum to the transverse colon and meso-colon is in conformity with the arrangement one sees in the adult body, and accords with the description usually found in the text books. But it should be stated, that observations have been made by various anatomists which prove that, in the fetus, the transverse meso-colon is a fold of the peritoneum quite distinct from the ascending layers of the great omentum, and that the arrangement seen in the adult is due to a secondary fusion of these peritoneal folds with each other.

descends in front of the aorta and lumbar spine into the pelvis, where it invests the upper end of the rectum and forms the *meso-rectum*. It only partially covers the second part of the rectum, and is reflected from it to the base and sides of the bladder to form the *posterior false ligaments of the bladder*. Between the bladder and the rectum the peritoneum forms a well-defined pouch, the *recto-vesical pouch*. In the female the uterus and vagina being interposed between the rectum and bladder, the disposition of the pelvic part of the peritoneum is modified as follows:—The membrane passes from the rectum to the upper end of the back of the vagina, and is then prolonged over the posterior surface of the uterus, the fundus uteri, and Fallopian tubes, and over about the upper two-thirds of the anterior surface of the uterus. From the sides of the uterus it is reflected to the sides of the pelvic cavity as the *broad ligaments* of the uterus, and from the front of the uterus to the back of the bladder. In both sexes the bladder has no peritoneal covering on its anterior wall, for the membrane is reflected from its sides to the pelvic wall, as the *lateral false ligaments*, and from its fundus along the line of the urachus to the anterior abdominal wall, as the *superior false ligament*.

The spleen is invested by the peritoneum, which is reflected from its hilus to the stomach, as the two layers of the *gastro-splenic omentum*, which again becomes continuous with the great omentum. The vessels and nerves which pass to the spleen lie between the two layers of the gastro-splenic omentum; those which go to the stomach between the two layers of the gastro-hepatic omentum, also between the two descending layers of the great omentum;

those which go to the liver between the two layers of the gastro-hepatic omentum. The vessels and nerves of the jejunum and ileum are between the anterior and posterior layers of the mesentery, and those of the transverse colon, sigmoid flexure, and rectum, between their respective mesenteric folds. Between the layers of the omenta, and those of the mesenteric folds, fatty tissue is developed, often in considerable abundance.

The general cavity of the peritoneum consists of two compartments, which communicate with each other through a constricted passage, the so-called *foramen of Winslow*. The larger of these compartments, or greater cavity of the peritoneum, is opened, when the anterior abdominal wall, and the parietal layer of peritoneum, which lines it, are cut through. It extends from the diaphragm above to the pelvis below, is in front of the stomach, great omentum, and intestine, and is the best known of the peritoneal compartments. The smaller compartment or *lesser cavity of the peritoneum*, lies behind the gastro-hepatic omentum and the stomach, and is prolonged downwards between the descending and the ascending layers of the great omentum as the *sac of the omentum*. Its posterior boundary is formed by the layer of peritoneum, which ascends in front of the pancreas to the diaphragm, to become continuous with the posterior layer of the coronary and the left lateral ligaments of the liver. It is closed in below by the omentum, transverse colon, and transverse meso-colon, and above by the liver, diaphragm, and coronary ligament. It is walled in on the left by the spleen and gastro-splenic omentum, whilst on the right it communicates with the greater cavity of the peritoneum through the foramen of Winslow.

This so-called foramen is not a hole, or break in the continuity of the peritoneal membrane, but a constricted passage, situated behind the right free border of the small omentum, where the portal vein, hepatic artery, and bile duct are ascending to the transverse fissure of the liver. The passage

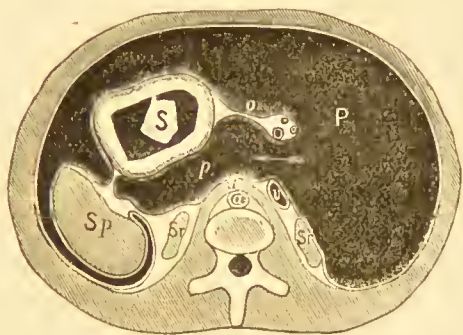


FIG. 183.—Diagram of a transverse section through the Abdomen and Peritoneum in the region of the lesser cavity of the peritoneum and of the Foramen of Winslow. *s*, stomach; *sp*, spleen. The stomach and spleen are attached together by the gastro-splenic omentum, *sr*, *sr*, supra-renal capsules; *d*, diaphragm; *a*, aorta; *i*, inferior vena cava; *o*, small omentum, with the portal vein, hepatic artery, and bile duct, transversely divided; *p*, lesser cavity of peritoneum; *P*, the greater cavity of peritoneum, the letter being placed in the position of the liver. The arrow is placed in the foramen of Winslow.

is bounded posteriorly by the peritoneal membrane covering the inferior vena cava; above it is bounded by the Spigelian lobe of the liver, and below by the duodenum. Through it not only does the greater cavity of the peritoneum communicate with the lesser, but the membrane lining the greater is continuous with that of the lesser cavity. The foramen is sufficiently large to admit of the passage of two fingers, and through their agency the extent of the lesser cavity may be examined. But a fuller view of this cavity may be obtained by detaching the great omentum from the greater curvature of the stomach and then drawing the stomach forwards. The prolongation of the lesser

cavity, as the sac of the omentum, between the ascending and the descending layers of the great omentum, is seen most readily in young persons ; for in adults it is not uncommon to find these layers fused together, or even riddled with numerous holes.

The parietal layer of the peritoneum is supplied with blood by the extra-peritoneal arterial plexus already described (p. 433). The visceral layer is supplied by branches of the arteries, which pass to the viscera that it invests. Lymphatic vessels form networks in the sub-endothelial layer of connective tissue, and communicate through microscopic stomata with the peritoneal cavity. Nerves pass to the diaphragmatic peritoneum from the phrenic nerve, to the parietal peritoneum of the lumbar regions from the lower intercostals, and to the pelvic peritoneum from some of the sacral nerves. Twigs from the sympathetic plexus apparently pass to the visceral peritoneum.

STOMACH.

The stomach is the bag-like dilatation of the alimentary canal, connecting the œsophagus with the duodenum, in which the food is mingled with the gastric juice, and converted into a pulpy substance—the chyme. The stomach is situated in the costal zone of the abdominal cavity; three-fourths of its volume, according to Luschka, being contained in the left hypochondrium, whilst the remaining fourth extends into the epigastrium. About five-sixths of the organ lies to the left of the mesial plane, and one-sixth to the right. The stomach varies in size, shape, and somewhat in position, according as it is empty or full of food. When moderately full it is about one foot in length, whilst its greatest transverse diameter is four to five inches. Its general shape is pyriform, and it may be described as possessing two extremities, two surfaces, and two borders. The larger extremity, called the *fundus*, *cardiac extremity*, or *great cul-de-sac*, is directed upwards so as to be in contact with the under surface of the diaphragm, whilst the smaller end, *pyloric* or *duodenal extremity*, is directed downwards, curves to the right, and becomes continuous with the duodenum. The *surfaces* form the *anterior* and *posterior walls* of the stomach. When the organ is empty, the walls are flattened, and in apposition with each other by their inner surfaces; but when it is distended they are curved; the anterior convex surface, directed forwards and upwards, is in relation with the anterior abdominal wall, the diaphragm, and the under surface of the liver; the posterior surface, also convex, directed

backwards and downwards, is in relation with the diaphragm, pancreas, transverse part of the duodenum,

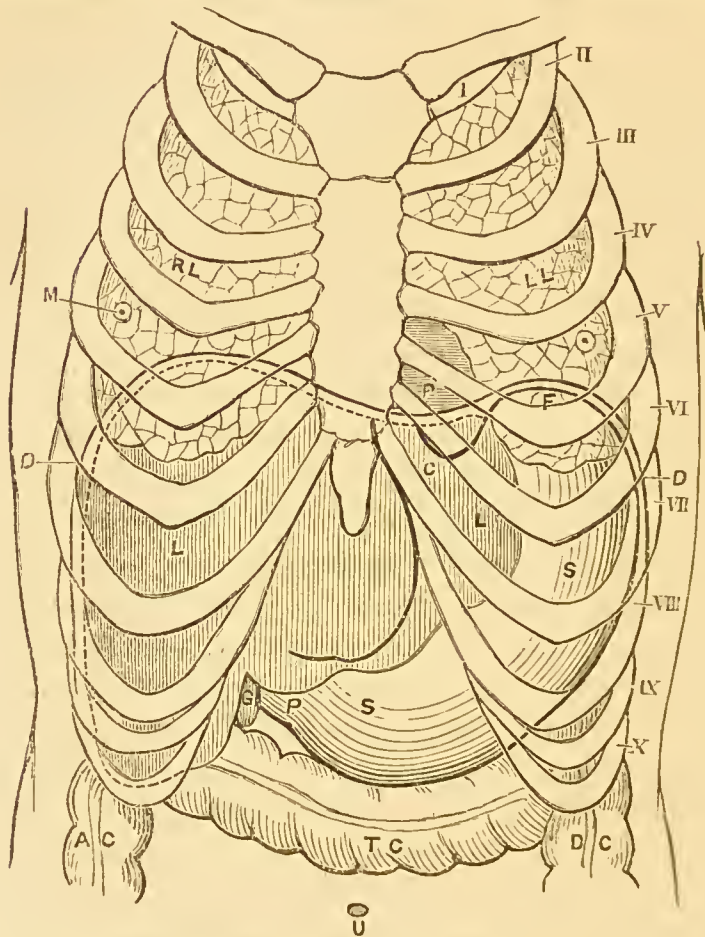


FIG. 184.-- The Lungs and their relations to the Diaphragm, Liver, and Stomach. II, to X, second to tenth ribs; DD, diaphragm; RL, right, and LL, left lung; P, pericardium; S.S, stomach; F is placed superficial to its fundus; P, its pylorus; C is over the cardiac orifice; L.L, the liver; G, gall bladder; AC, ascending, TC, transverse, and DC, descending colon; U, umbilicus; M, right nipple. Modified from Luschka.

spleen, left kidney, and supra-renal capsule. The borders of the stomach are curved and unequal in size; one is convex, about three times as long as the other, and

is named the *greater curvature*; the other is concave, and forms the *lesser curvature*. The curvatures are so arranged that the greater has its convexity directed downwards and to the left, where it lies in relation to the transverse colon and the splenic flexure of the colon. The lesser curvature has its concavity directed upwards and to the right; for the most part it is to the left side of the spinal column with which it is almost parallel; it lies in relation to the coeliac axis. The œsophagus opens into the stomach at the upper end of the lesser curvature, and the cardiac orifice lies behind and opposite to the sternal fourth of the seventh left costal cartilage. Above this orifice the stomach expands into the fundus, which is situated in the highest part of the left hypochondrium, and occupies therefore the summit of the vault of the left half of the diaphragm. At the lower and right end the two curvatures lie almost horizontally in the epigastrium and terminate at the pylorus, where the stomach becomes continuous with the duodenum. The pylorus, or gate of the stomach, is situated in the epigastrium about three fingers' breadth below the ensiform cartilage, and immediately to the right of the mesial plane. The junction of the stomach with the duodenum is marked by a circular constriction externally, called the *pyloric constriction*, and by a valve internally, the *pyloric valve*. At its pyloric end the stomach presents a small bulging, the *lesser cul-de-sac*, or *antrum pylori*. Occasionally another constriction surrounds the stomach between its pyloric and œsophageal portions, so as to give it the appearance of an hour-glass, and imperfectly to separate it into two chambers.

The stomach does not, as has often been stated, lie

transversely across the abdominal cavity, but, as has been clearly pointed out by Luschka, is for the most part placed vertically in the left hypochondrium, so that the fundus is the uppermost part of the organ; whilst the pylorus, which curves to the right into the epigastrium, forms its lower extremity. Owing to the vertical direction of the stomach in the left hypochondrium, the 5th, 6th, 7th, 8th, and 9th ribs, separated of course by the diaphragm, arch in front of it, for a greater or less distance; and its fundus, the diaphragm intervening, is in relation to the base of the left lung, the heart, and pericardium. When greatly distended the stomach acquires more extensive relations. It may push the transverse colon to one side, and may reach into the umbilical, left lumbar, or even the left iliac region. Its fundus also may press upwards the left half of the diaphragm, interfere with the descent of that muscle during deep inspiration, and affect the position and action of the heart. In the distended condition the greater curvature of the stomach is thrown forward, so as to lie in relation to the anterior abdominal wall.

The stomach is retained in position, partly by its connections with the œsophagus and duodenum, partly by the pressure of the surrounding abdominal walls and viscera, and partly by folds of peritoneum which pass from it to the adjacent structures. These folds are as follows:—The *gastro-phrenic ligament* extends from the diaphragm to the stomach in the angle between the œsophagus and the cardiac extremity: the *gastro-hepatic*, or *small omentum*, passes from the lesser curvature of the stomach to the lips of the transverse fissure of the liver; the *gastro-splenic omentum* from the cardiac end of the stomach to the

spleen ; the *gastro-colic*, or *great omentum*, descends from the greater curvature of the stomach in front of the coils of the small intestine, and then ascends to enclose the transverse colon.

Structure of the Stomach.

The wall of the stomach consists of four coats, named from without inwards, serous, muscular, sub-mucous, and mucous coats.

The *external* or *serous coat* is that part of the peritoneal membrane which encloses the stomach ; one layer covering the anterior, the other the posterior surface. It leaves the stomach at the curvatures, where it forms the great and small omenta, and along these borders the two layers enclose between them the blood-vessels and nerves which supply the organ. The serous coat is loosely united to the subjacent muscular coat by areolar tissue, which is sometimes called the *sub-serous coat*.

The *muscular coat* consists of non-stripped fibres arranged in three layers from without inwards. The outer layer consists of *longitudinal* fasciculi, which are continuous with the external longitudinal layer of the œsophagus. They form scattered fasciculi extending longitudinally over the surface of the stomach from cardia to pylorus, but along the two curvatures, more especially the lesser, they are collected into stronger bundles, and at the pylorus become continuous with the longitudinal fibres of the duodenum. The middle layer consists of *circular* fasciculi, which form a ring-like arrangement transversely to the long axis of the stomach. These fasciculi are comparatively thin and scattered at the cardiac end, but as they approach

the pylorus, they become more closely aggregated, so as to form a thick layer, which at the pylorus extends into the pyloric valve, and forms the *sphincter pylori* muscle. The circular fibres of the stomach are in the same morphological plane as the circular fibres of the œsophagus and duodenum. The inner layer consists of *oblique* fasciculi, which are not found over the entire organ ; the greater number spring from the left side of the cardiac orifice, and radiate on the anterior and posterior surfaces towards the pylorus and greater curvature. Henle and Pettigrew have described a group of short oblique fasciculi as spreading from the right side of the cardiac orifice over the anterior and posterior surfaces of the fundus, and the latter author has described oblique fibres investing the pylorus ; Pettigrew indeed considers that the circular layer consists of very oblique fibres intersecting each other in figure of eight loops. These oblique fibres by their contraction approximate the cardia to the pylorus, the great curvature to the smaller, and the anterior to the posterior wall : they are thus the true grinding muscles of the stomach, and have been compared to the muscular gizzard of the bird. From the relation of the two groups of oblique fibres to the cardiac orifice they probably close that opening during gastric digestion. The longitudinal and circular fibres occasion a longitudinal shortening and transverse constriction of the stomach. By the action of the muscular coat the food is churned about in the stomach, so as to become thoroughly intermingled with the gastric juice. The contraction of the sphincter pylori closes the pyloric orifice, and prevents the passage of the food into the duodenum, before it is converted into chyme.

The *submucous coat* lies immediately subjacent to the oblique layer of the muscular coat, and forms the bond of union between that coat and the mucous membrane. It consists of the areolar variety of connective tissue, mingled with elastic fibres, and in it the blood-vessels ramify before they pass into the mucous membrane.

The *mucous* or *internal coat* lines the cavity of the stomach, and is continuous with the mucous membrane of the œsophagus and duodenum. It is a soft, pulpy mem-

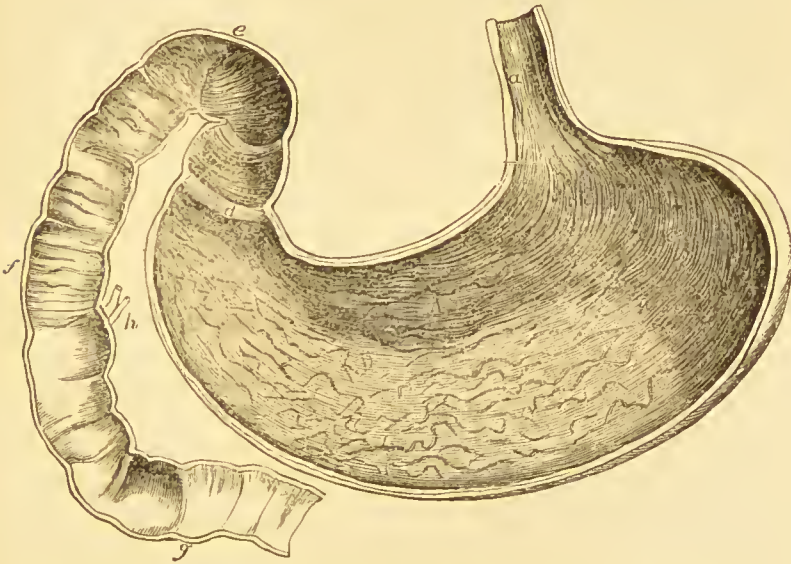


FIG. 185.—The mucous coat of the Stomach and Duodenum, showing the rugæ of the stomach and the valvulæ conniventes of the duodenum. *a*, œsophagus; *c*, cardiac end of stomach; *d*, pyloric valve; *e*, ascending, *f*, descending, and *g*, transverse parts of duodenum; *h*, biliary and pancreatic ducts.

brane, of a pink colour, which becomes redder during digestion, owing to turgescence of the blood-vessels. At the pyloric end it is often stained yellow or green with bile, and in old people it has a brown colour, from formation of pigment. In the empty stomach it is thrown into

folds or *rugæ*, which have usually a longitudinal direction, but when distended the *rugæ* are obliterated, and the surface of the mucous membrane is smooth. This membrane is usually said to be thicker at the pyloric end than in the fundus; but Brinton, who had opportunities of examining the stomach of healthy young adults immediately after death, found the cardiac mucous membrane to be more than twice as thick as the pyloric: he ascribes the thinning of the cardiac mucous membrane to the effects of post-mortem digestion, owing to the gravitation of the gastric juice, in the recumbent position of the dead body, into the fundus of the stomach.

If the free surface of the gastric mucous membrane be examined with a pocket lens it will be seen to be pitted with shallow depressions or alveoli, polygonal in form, and varying from $\frac{1}{100}$ th to $\frac{1}{200}$ th inch in diameter. In the sides and bottom of each of these pits numerous rounded orifices may be seen, which are the mouths of the gastric secreting glands. If vertical sections be now made through the mucous membrane, these glands will be seen to be tubular in form. They are closely crowded together, and extend through the thickness of the mucosa; their deeper closed extremity being in relation to the submucous coat, whilst the open mouth of the gland is at the surface of the mucous membrane.

In the human stomach the tubular glands are, for the most part, simple, almost straight cylinders, and possess an average length of $\frac{1}{25}$ th inch, and a breadth of about $\frac{1}{350}$ th inch. They are somewhat dilated at their orifices, and at their closed ends give rise to cœcal pouches. The wall of the tubes consists of a condensation of the inter-

glandular connective tissue, which forms a *membrana propria*; flat stellate cells are said to occur in it. For about the upper fourth or fifth of their length the tubes are lined by a single layer of columnar epithelium, continuous with the columnar epithelium covering the free surface of the gastric mucous membrane. In these columnar cells the nucleus is situated close to the attached end of the cell. In the rest of the gland-tube Brinton found two kinds of cells. The one consisted of the so-called *peptic cells*, about $\frac{1}{1200}$ th inch in diameter, and of an ovoid or somewhat polygonal form, which lay next to the wall of the gland. The other kind, somewhat cubical in form, lined the very narrow central canal of the gland, and formed an *axial layer*, which was continuous above with the columnar epithelium lining the upper end of the tube. Brinton stated that this dimorphous structure of the gastric glands exists throughout the vertebrata.

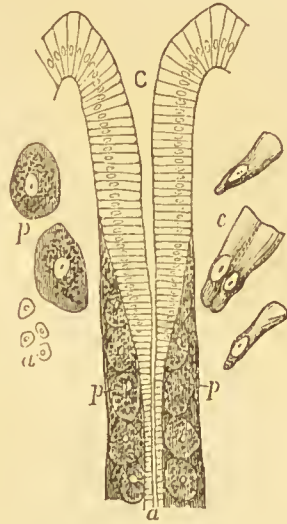


FIG. 186. — Upper part of a gastric gland from the middle of the human Stomach. *c*, columnar epithelium; *a*, axial cells; *p*, peptic cells. $\times 200$. More highly magnified views of these cells when isolated are also given. From Brinton.

It is in the dog and cat, however, that the structure of the gastric mucous membrane has especially been studied, and two kinds of glands have been described. The one, situated especially in the region of the pylorus, consists for the most part of simple tubes, which may however

branch at their deeper end : they have been called the *mucous glands*. They are lined by a columnar epithelium, the cells of which at the deeper end of the gland are more cubical in form, and have a clouded granular appearance. The other kind of gland is situated in the remaining part of the gastric mucous membrane, and consists of tubes which divide usually into four branches ; they have been named the *peptic glands*. The cellular lining of

these peptic glands closely corresponds with the dimorphous arrangement in the human stomach already referred to. The two forms of cells in the deeper branched part of the gland were first observed by Kölliker in the dog, and have since been specially studied by Heidenhain, Rollett, and Frey. According to the last two observers, the axial layer of cells is absent in a certain extent of the gland tube, below the place where the columnar epithelium ceases, and the cellular lining consists merely of a continuous layer of peptic cells. In the deeper part of the gland again, both kinds of cells occur. Hei-



FIG. 187. — Vertical section through the Gastric mucous membrane of a cat, to show the tubular peptic glands. *c*, columnar epithelium near the gland mouth; *p*, peptic cells; *m*, interglandular muscular band; *v*, vessels surrounding tubular gland. *mm*, muscularis mucosae; *sm*, submucous coat.

denhain states that in a fasting dog the glands are shrunken, and the axial cells are transparent, whilst during digestion the peptic glands are swollen out and the cells are clouded and granular.

The gastric glands are separated from each other by slender prolongations of the muscularis mucosæ, and by the vascular interglandular connective tissue, which is soft, delicate, and contains a small proportion of lymphoid corpuscles diffused in it. In some localities the lymphoid tissue may be collected into solitary follicles, forming the *lenticular* glands of the stomach. Beneath the glands is a well defined *muscularis mucosæ*, arranged in two layers, which gives off bundles that pass between the gastric glands.

The gastric mucous membrane is highly vascular: small arteries enter it from the submucous coat, and terminate in a capillary plexus, situated in the interglandular connective tissue surrounding the gastric glands; a vascular capillary ring surrounds the orifice of each gland.

The *pyloric valve* is the name given to the circular fold, situated at the junction of the stomach and duodenum, which surrounds the pyloric orifice. This fold is covered on its free surface by mucous membrane, which encloses the submucous coat and the circular layer of the muscular coat, but not the longitudinal layer, or the serous coat. That portion of the mucous membrane which covers the gastric surface of the valve possesses the structure of the mucous membrane of the stomach; whilst that which covers the duodenal surface is studded with villi, and possesses the structure of the intestinal mucous membrane.

The arteries of the stomach are the coronary branch of the celiac axis, and branches of the hepatic and splenic arteries. They form, as already described (p. 427), arterial arches along the greater and lesser curvatures, and

anastomosing arrangements in the anterior and posterior walls of the stomach. The veins of the stomach are rootlets of the portal vein. The lymphatics are numerous, and form a superficial and a deep set. The superficial run along the curvatures. The deep lymphatics arise in the gastric mucous membrane, where they form a network between the glands: they pierce the submucous and muscular coats, and join the superficial lymphatics. The nerves of the stomach are derived from the epigastric plexus of the sympathetic and from the pneumogastric nerves. The right vagus ends in the posterior wall of the stomach, the left in the anterior wall. Nerve cells are met with in relation to the nerves both in the muscular and submucous coats.

INTESTINAL CANAL.

The Intestinal Canal, Intestine, Gut, or Bowel, is situated in the abdominal cavity, and extends from the pyloric opening, or gate, of the stomach to the orifice of the anus, where it opens on the surface of the body in the region of the perineum. In it the chyme becomes mingled with the bile, the pancreatic fluid, and the secretions of the intestinal glands, and is converted into chyle. In it also the absorption of the chyle takes place, and the insoluble part of the food is passed onwards to be excreted in the form of fæces. The intestine is the longest division of the alimentary canal, and measures on an average about twenty-five feet. It is primarily divided into two parts, called small intestine and large intestine; the length of the small is about twenty feet, that of the large about five feet.

The SMALL INTESTINE is the upper of the two divisions of the canal, and consists of a convoluted, almost cylindrical tube, which reaches from the pylorus to the cœcum, or commencement of the large intestine. It is sub-

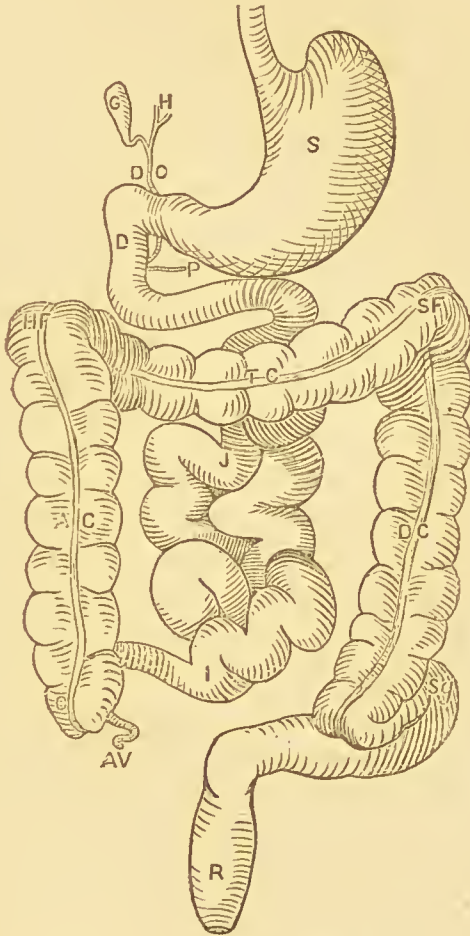


FIG. 194.—Diagram of the abdominal part of the Alimentary Canal. S, stomach; D, duodenum; J, jejunum; I, ileum; AV, appendix vermiformis; AC, ascending colon; HF, hepatic flexure; TC, transverse colon; SF, splenic flexure; DC, descending colon; SG, sigmoid flexure; R, rectum; G, gall bladder; H, hepatic duct; DC, common bile duct; P, pancreatic duct.

divided into three portions, named duodenum, jejunum, and ileum.

The DUODENUM is the commencement of the small intestine, and has received its name from its length being regarded as about equal to the breadth of twelve fingers. It forms the shortest and widest of the three sub-divisions of the small bowel; it curves, in the form of a horse-shoe, from the pylorus to opposite the left side of the body of the second lumbar vertebra, where it becomes continuous with the jejunum. It is customary to regard it as consisting of three parts, an ascending, a descending, and a transverse. The ascending part runs from before backward slightly upwards and to the right, from the epigastrium into the right hypochondrium, where it comes in contact with the under surface of the liver and gall bladder, and is usually stained green by the bile. The descending part passes downwards into the right lumbar region, as far as the second or third vertebra. It lies between the pancreas and right kidney, goes behind the transverse colon and the meso-colon; and the common bile duct, running down behind its left border, perforates its wall along with the pancreatic duct.

The transverse part extends into the umbilical region, lies behind the stomach and transverse colon, and becomes continuous with the jejunum at the line where the small intestine is crossed by the superior mesenteric artery. The head of the pancreas lies in the concavity of the horse-shoe curve of the duodenum.

The duodenum is that part of the small intestine which is most fixed in its position. Its ascending part is connected to the liver by a fold of peritoncum, sometimes

called the *hepatico-duodenal ligament*, and its descending and transverse parts are attached to the right kidney and posterior wall of the abdomen by connective tissue. But in addition a *suspensory muscle*, composed of non-stripped fibres, has been described by Treitz as extending from the region of the cœliac axis and superior mesenteric artery to the transverse part of the duodenum.

The duodenum is distinguished from the rest of the small intestine by having the ducts of the liver and pancreas opening into its canal, by containing in its wall a collection of compound racemose glands, named the glands of Brunner, and by being developed from the primitive fore-gut, and not, like the jejunum and ileum, from the primitive middle gut (p. 774). Like the stomach, it should be regarded as a distinct segment of the alimentary canal.

The JEJUNUM and ILEUM form by far the longest part of the small intestine, and are not separated from each other by any sharp line of demarcation : the upper two-fifths being called jejunum, on account of its being usually empty after death, the lower three-fifths being termed ileum, from its convoluted arrangement. They occupy the umbilical, hypogastric, right and left iliac regions of the abdomen, in which they are arranged in a series of coils or convolutions ; one or two coils of the ileum sometimes lie in the cavity of the pelvis, between the bladder and rectum. The coils are attached to the posterior wall of the abdomen, along a line from the body of the first lumbar vertebra to the right sacro-iliac joint, by the fold of peritoneum called the *mesentery*. Owing to the extent of the mesentery, the coils of the jejunum and ileum can

be freely moved about in the abdominal cavity, so that they are apt to be displaced from their natural position, and, when a rupture occurs, to become the most usual contents of the hernial sac. The lower end of the ileum passes into the right iliac fossa, where it becomes continuous with the large intestine, at the junction of the cœcum and ascending colon. Though the line of demarcation between jejunum and ileum is an arbitrary one, yet the upper end of the jejunum may be distinguished from the lower end of the ileum by being wider, and having a thicker mucous membrane, in which the folds called *valvulæ conniventes* are larger and more numerous.

There is occasionally found projecting from the lower third of the ileum a short prolongation of that tube, which forms an elongated hollow process, terminating at its free end in a *cul-de-sac*. It is named *diverticulum ilei*. It may vary in length from half-an-inch to six or seven inches, and usually projects from the convex aspect of the circumference of the bowel. On rare occasions it has been seen to be attached to the wall of the abdomen in the region of the navel by a slender band of fibrous tissue. The diverticulum is of interest as representing a persistent condition of the omphalo-mesenteric or vitello-intestinal duct, which in the embryo connects the umbilical vesicle with the primitive intestine.

Structure of the Small Intestine.

The wall of the small intestine consists in the greater part of its extent, of four coats, named from without inwards, serous, muscular, submucous, and mucous coats.

The *serous*, or *external coat*, derived from the peritoneum, forms a complete investment for the jejunum and ileum, and is continuous with the mesentery along a line of attachment, named the mesenteric border of the intestine. The ascending part of the duodenum also has a complete serous coat, but the serous covering of the descending and transverse portions is limited to their anterior surface. The serous coat of the small intestine is loosely united to the subjacent muscular coat by areolar tissue, which is sometimes called the *subserous coat*.

The *muscular coat* consists of non-striped fibres arranged in two layers from without inwards. The outer layer consists of *longitudinal* fasciculi, which form a thin layer parallel to the long axis of the intestine. The inner layer consists of *circular* fasciculi arranged around the gut transverse to its long axis : this layer is thicker, stronger, and more highly coloured than the longitudinal layer. By the contraction of the muscular coat, the peristaltic or vermicular movement is produced, which propels the ingested materials along the intestine.

The *submucous coat* lies immediately subjacent to the circular layer of the muscular coat, and forms the bond of union between that coat and the mucous membrane. It consists of areolar connective tissue, and in it the blood-vessels ramify before they pass into the mucous membrane.

The *mucous*, or *internal coat*, is a soft, velvety-looking membrane, which lines the wall of the small intestine, and possesses a complex appearance and structure. The inner surface is not smooth, but is thrown into strongly-marked folds, the *valvulae conniventes*, which are not obliterated

during distension of the gut. The folds are placed transversely to the long axis of the bowel, and run around its inner wall for one-third or one-half, or two-thirds of its circumference (fig. 185). They project into the lumen of the intestine, and the largest are about one-third of an inch in depth. They are first seen about the commencement of the descending part of the duodenum, are very numerous in the transverse part of the duodenum and upper half of jejunum, then decrease in size and numbers, until at the lower end of the ileum they have disappeared. Each *valvula* consists of a fold of the mucous membrane with its submucous coat. Owing to their presence, the extent of the mucous surface is much greater than if it were a plane-surfaced membrane.

In its more minute structure the mucous coat may be regarded as composed of projecting bodies, a glandular layer, and a muscular layer.

The projecting bodies are the intestinal *Villi*, which jut out into the lumen of the intestine from the free surface of the mucous membrane, not only of the *valvulæ*, but of the intermediate surface. They are delicate minute processes, varying in length from a fourth to half a line, and in number amount to several millions.

They are best examined when the mucous surface is placed in water or spirit, when they may be seen with the naked eye, or still better, with a pocket lens; when the chyle-vessels or blood-vessels are injected, they become erected, and stand out more prominently from the surface. They vary in form, being filiform, or cylindrical, or conical, or club-shaped, or leaf-shaped. They are more numerous in the duodenum and jejunum than in the

ileum, and to their presence is due the velvety appearance of the mucous surface. They are not found elsewhere than in the small intestine.

As they are the parts of the mucous membrane directly concerned in the absorption of the chyle, their structure is interesting and important. Each villus is invested by a cap of epithelium continuous with the general epithelial covering of the mucous membrane. The epithelium consists of a single layer of *columnar cells*, compactly arranged side by side. The deep attached end of the cell is frequently attenuated into a slender filament. The broad free end, as was first figured by Goodsir, possesses a border distinct from the general body of the cell. Kölliker and Funke recognised in this border vertical striæ, which they regarded as minute canals, for the transmission of the particles of the chyle, but which are probably nothing more than a peculiar vertical arrangement of the cell-protoplasm at the border of the cell (fig. 31, C). Occupying the intervals between the attenuated ends of the



FIG. 189.—Vertical section through the mucous membrane of the Small Intestine, showing the villi and glands of Lieberkühn. 1, villus covered by epithelium; 2, vertical section through a villus, showing the lacteal; 3, blood vessels of the villus; L, the layer of glands of Lieberkühn; c, capillaries surrounding one of these glands; m,m, muscularis mucosæ. $\times 40$.

attached cells are minute *supplementary cells*, sometimes globular in shape, at others elongated and somewhat caudate. Scattered amidst the columnar cells are cells which possess the form of microscopic goblets, and are named *goblet cells*. The free end of each goblet cell appears to have an open mouth on the surface of the villus, through which a mucous-like substance exudes. Various opinions have been expressed as to the nature of these goblet cells. Some regard them as special structures engaged either in the absorption of chyle, or the secretion of mucus: others look upon them as merely modifications of the columnar epithelium: whilst others again consider them to be *post-mortem* productions, due to the swelling out of the columnar epithelium by the imbibition of fluid. There can be no doubt, however, that they are not specially concerned in the absorption of chyle, as cells of the same character are found in the respiratory mucous membrane, and on other surfaces, where the absorption of chyle does not take place.

The sub-epithelial tissue of a villus forms its matrix or basis substance, and consists of the sub-epithelial connective tissue of the mucous membrane. When thin sections through a villus are examined, the matrix is seen to be composed not of areolar tissue, but of a delicate retiform tissue, which forms a network, between the periphery of the matrix and the wall of the chyle vessel, and in the meshes of this network numbers of colourless lymphoid corpuscles are imbedded. These cells were described and figured by Goodsir, as the absorbing cells or vesicles of the villus. Immediately beneath the epithelium, the matrix appears, from Krause's observations, as if its corpuscles were flat-

tened into irregular scales. H. Watney states that a delicate reticulum continuous with the most superficial layer of corpuscles of the connective tissue is prolonged between the epithelium cells. In the axis of the villus one, or perhaps two, minute lacteals or chyle vessels are situated, which serve as rootlets of origin of the lacteal division of the lymph vascular system. The lacteal is a capillary tube, which ends near the apex of the villus, as a dilated microscopic *cul-de-sac*. By its opposite extremity it becomes continuous with a plexus of lacteals in the submucous coat. When treated with nitrate

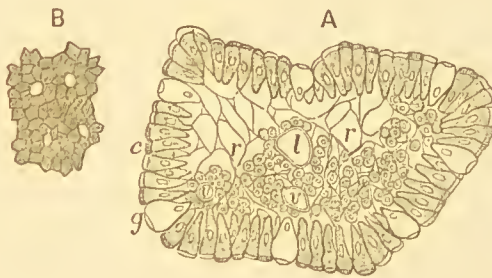


FIG. 190.—A transverse section through an intestinal Villus A, showing its epithelial investment and the matrix of Lymphoid tissue; c, columnar epithelium; g, goblet-shaped cell; l, lacteal; r, r, lymphoid retiform tissue; v, v, transversely divided blood-vessels. B, free ends of columnar epithelium, with mouths of four goblet-shaped cells. $\times 300$.

of silver, its wall is seen to consist of flattened endothelial cells, which are connected with the retiform tissue of the matrix substance. In the matrix substance, around the lacteal vessel of the villus, is a layer of non-striped muscular fibro-cells, which is continuous with the general muscular layer of the mucous coat, and extends as far as the apex of the villus. By the contraction of this layer the chyle during absorption is propelled along the lacteal

vessel, and a wrinkled or puckered condition of the villus, sometimes seen after death, is occasioned. The villus also contains blood-vessels; a small artery enters at its attached base, and terminates in a capillary plexus, situated in the peripheral part of the matrix, close to the cap of epithelium; from the plexus a vein arises, which leaves the villus at its base, and joins the veins in the sub-mucous coat.

Various theories have been put forward to account for the mode of passage of the chyle, during digestion, from the lumen of the intestine into the lacteal vessels of the villi; but the question cannot even yet be regarded as definitely settled. The appearance of a network of minute tubules within the matrix, extending from the epithelial investment to the lacteal, which Letzerich supposed to be the channels along which the chyle flowed, is doubtless produced by the arrangement of the strands of the retiform tissue. There seems little doubt, that both the cells of the epithelial investment, and those of the retiform tissue of the matrix, become distended with the particles of chyle previous to its passage into the lacteal. The view advanced by Schäfer, that the corpuscles in the meshes of the retiform tissue may serve as carriers of the fatty particles of the chyle into the lacteals, is but another mode of expressing the function of these cells advocated thirty years ago by Goodsir.

The mucous membrane of the small intestine is abundantly provided with secreting glands, named the glands of Brunner and of Lieberkühn.

Brunner's glands are confined to the duodenum; they belong to the compound racemose group of glands, and

resemble generally in structure the mucous and salivary glands. The minute lobules of these glands lie in the submucous coat, and the excretory duct pierces the mucous membrane to open on the surface. The wall of the duct is formed of connective tissue lined by columnar epithelium. The finest branches of the duct are continuous with the acini or gland vesicles, and W. Krause states that their membrana propria consists of a layer of polygonal flattened cells. The gland vesicles contain the secreting cells, which are columnar in form: and Schwalbe has described inter-cellular passages, between these cells which communicate, as in the salivary glands, with the excretory duct. A plexus of capillary blood-vessels is distributed outside the membrana propria of the gland vesicles, and lymphatic vessels lie around the lobules. Into the duodenum, about the junction of its descending and horizontal portions, the duct of the pancreas, and the bile duct from the liver, open by a common orifice. These glands may be regarded therefore as accessory glands to this portion of the small intestine.

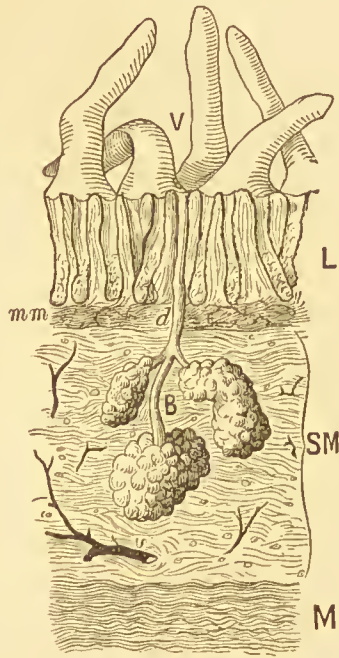


FIG. 191.—Vertical section through the wall of the duodenum, showing the Glands of Brunner. V, intestinal villi; L, layer of glands of Lieberkühn; *m, m*, muscularis mucosæ; B, a Brunner's gland, *d*, its excretory duct; SM, submucous coat; M, muscular coat; *v*, a small artery. $\times 40$.

The glands of *Lieberkühn* are distributed throughout the whole length of the mucous coat of the small intestine. They are simple tubular glands, in form like test tubes, which lie vertically in the mucous membrane, and

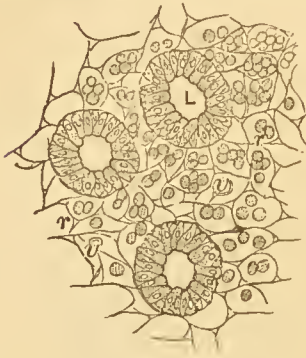


FIG. 192. — Horizontal section through the mucosa of the small intestine, to show the Glands of Lieberkühn, L, and the interglandular retiform lymphoid tissue, r, r. v, v, transversely divided blood vessels. $\times 300$.

form its proper glandular layer (figs. 189, 191.) The tubes are microscopic in size, vary in length from $\frac{1}{10}$ th to $\frac{1}{30}$ th of a line, are sometimes closely set together, but in the localities where the solitary and Peyer's glands occur, they are more widely separated. The glands open on the surface of the mucous membrane between the villi; and the opposite end of the tubes is closed and rounded, and reaches close to the mus-

cular layer of the mucous coat. They are lined by a layer of columnar epithelium cells, continuous with the epithelial investment of the villi; supplementary and goblet cells, similar to those described on the villi, are situated between the columnar cells. The glands are separated from each other by retiform connective tissue, in the meshes of which colourless lymphoid corpuscles exist in considerable numbers; the plexus of capillary blood-vessels, which is distributed outside the membrana propria of the gland tube, lies in this connective tissue.

The connective tissue of the mucous coat is characterised generally by its retiform character, and by the diffusion of colourless lymphoid corpuscles in the meshwork. But

in some parts of the mucosa these corpuscles, with their supporting framework of retiform tissue, are collected into distinct masses or follicles, visible to the naked eye, and known in descriptive anatomy as the solitary and Peyer's glands or follicles.

The *solitary glands* are scattered throughout the whole length of the intestinal mucous membrane. They are about the size of millet seeds, and vary in number and distinctness in different individuals. They are globular or ovoid in form, and occasion a slight elevation of the mucous membrane. One pole of the gland, sometimes named the cupola, lies next the free surface of the mucous membrane, and is in relation to the columnar epithelium covering the mucosa, whilst the opposite pole, or base, rests on the submucous coat.

Peyer's glands, or the *agminated glands*, consist of an aggregation of solitary glands or follicles, which are crowded together, so as to form distinct elongated patches, which may vary in length from one quarter inch to three or four inches. The long axis of each patch corresponds to the long axis of the intestine, and the patches are placed opposite to the mesenteric attachment of the bowel. Villi either may, or may not, be situated on the surface of the patch, in the intervals between the individual follicles, but Lieberkühnian glands are always found opening on the surface, and frequently forming a ring of orifices around each follicle. Peyer's patches are most abundant in the lower end of the ileum, but diminish in size and numbers in its upper end and in the jejunum, and are absent in the duodenum.

These follicles are lymphoid organs, and are composed of

lymphoid tissue, as has been described on p. 548, where an account of the arrangement of their blood-vessels and lymph-vessels has also been given. The solitary and Peyer's glands, as is the case generally with the lymphoid organs, are more distinct and perfect in structure in infancy and childhood, than in adults or in advanced age.

Peyer's glands are the seats of tubercular formation in tubercular disease of the intestine; and they become swollen and ulcerated in the typhoid form of continued fever. The changes which take place in these glands in the course of typhoid ulceration is due, as was pointed out by Goodsir, to the great development of cells within the constituent follicles of a patch, which in consequence burst and give rise to an ulcerated surface.

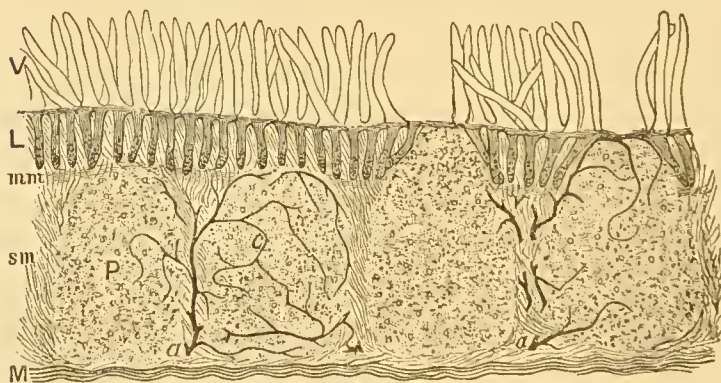


FIG. 193.—Vertical section through a Peyer's patch in the wall of the small intestine. V, the intestinal villi; L the layer of Lieberkühn's glands; mm, the muscularis mucosæ; sm, the connective tissue of the submucous coat; P the follicles of a Peyer's patch. The two to the right are completely divide from the enpola to the base; the two to the left are cut through to one side o the apex; aa, small arteries in the submucous coat, which enter the follicles o Peyer, and form, c, a capillary network; M, muscular coat. Slightly magnified

The *muscular layer* of the mucous membrae lies next to the submucous coat. It was discovered by Brücke, and

consists of non-striped fibres which lie parallel to the surface of the membrane. It passes also into the substance of the villi, and lies around the closed end of the glands of Lieberkühn; but, where the solitary and Peyer's glands are situated, it is perforated, to allow the base of the follicle to reach the submucous coat.

Of the *blood-vessels* of the small intestine, the arteries enter the wall of the jejunum and ileum at its attached or mesenteric border, and are branches from the arcades of the superior mesenteric artery; whilst the arteries for the duodenum are the superior pancreatico-duodenal of the gastro-duodenal branch of the hepatic artery, and the inferior pancreatico-duodenal branch of the superior mesenteric. They run in the sub-serous tissue around the wall of the intestine; then pierce the muscular coat and supply it; they then enter the sub-mucous coat, and form a network from which branches pass into the mucous coat. The veins accompany the arteries, and form rootlets of the superior mesenteric vein.

The *Lymph-vessels*, or *lacteals*, may be traced into the wall of the intestine at the mesenteric border; they form a network in the muscular coat, and then enter the sub-mucous coat, where they are very abundant; from this sub-mucous layer offshoots pass through the retiform tissue, which lies between the Lieberkühnian glands, into the villi. Where the solitary and Peyer's glands are situated the lacteals, as Frey has pointed out, form a system of anastomosing vessels around the base and mesial part of each follicle.

The *nerves* are derived from the plexuses of the sympathetic, which accompany the branches of the superior

mesenteric artery. They form between the two layers of the muscular coat an important plexus, named after its discoverer, Auerbach's plexus, in which large stellate nerve-cells are intermingled with nerve fibres, and a similar nervous plexus is found in the muscular coat of the other divisions of the alimentary canal. It supplies and regulates the movements of the muscular coat. In the submucous coat is found a nervous plexus, named Meissner's plexus, after its discoverer, in the strands of which nerve-cells are collected into gangliform masses, and a similar plexus is found in the submucous coat of the other divisions of the alimentary canal. Auerbach's plexus is connected with Meissner's plexus by intercommunicating fibres; and fibres pass from Meissner's plexus to the muscularis mucosæ, to the glandular layer of the mucous coat, and to the attached base of the villi.

The LARGE INTESTINE, though not nearly so long as the small intestine, is of much greater diameter. It reaches from the end of the ileum to the orifice of the anus, and is divided into the cœcum with the appendix vermiformis, the colon, and the rectum; whilst the colon is subdivided into the ascending colon, the hepatic flexure, the transverse colon, the splenic flexure, the descending colon, and the sigmoid flexure.

The CŒCUM is the commencement of the large intestine, and lies below the ileum. It occupies the right iliac fossa, and is attached by areolar tissue to the fascia covering the iliacus muscle. Sometimes it is displaced from this position and hangs down into the true pelvis; more rarely it is elevated into the right lumbar region. It is the most

dilated part of the large intestine, and forms a large *cul-de-sac*, closed in below, but communicating freely above with the ascending colon. Opening on the inner and posterior wall of the cœcum is the *Appendix vermiformis*, which is a slender hollow prolongation of the bowel, varying in length from three to six inches. It has the calibre of the stem of a common tobacco pipe, and ends in a free closed extremity, so that, like the cœcum, it is a *cul-de-sac*. It possesses a peritoneal fold or small mesentery, by which it is sometimes tied to the adjacent wall of the abdomen, though at other times it may be freely movable. It is not generally found in mammals, but is present in man, the orang, certain lemurs, and the marsupial wombat.

THE ASCENDING OR RIGHT COLON is continuous below with the cœcum and above with the hepatic flexure. It occupies the right lumbar region, and is attached by areolar tissue to the fascia covering the quadratus lumborum muscle and to the front of the right kidney.

THE HEPATIC FLEXURE OF THE COLON is a bend in the large intestine, forming almost a right angle, continuous on the one hand with the ascending colon, and on the other with the transverse colon. It lies in the right hypochondriac region in contact with the under surface of the liver.

THE TRANSVERSE COLON connects the hepatic and splenic flexures, and curves across the abdomen from the right hypochondrium, through the umbilical region to the left hypochondrium. It forms the arch of the colon, the convexity of which is directed downwards and forwards, and the concavity upwards and backwards. It lies immediately below the great curvature of the stomach, and is

connected with the posterior layer of the great omentum. Owing to the length of the *transverse meso-colon*, which forms its peritoneal attachment, it not unfrequently undergoes some change in its position, and may hang down-

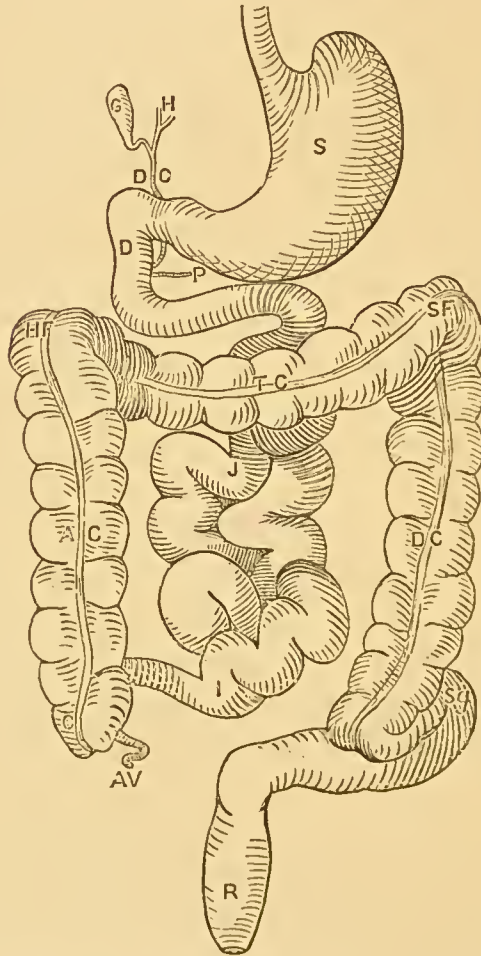


FIG. 194.—Diagram of the abdominal part of the Alimentary Canal. S, stomach; D, duodenum; J, jejunum; I, ileum; AV, appendix vermiformis; AC, ascending colon; HF, hepatic flexure; TC, transverse colon; SF, splenic flexure; DC, descending colon; SG, sigmoid flexure; R, rectum; G, gall bladder; H, hepatic duct; DC, common bile duct; P, pancreatic duct.

wards towards the pelvis, or be elevated in front of the stomach, or thrown to the right or left side. This tendency to displacement of the transverse colon should be kept in mind in the diagnosis of diseases of the abdominal viscera.

THE SPLENIC FLEXURE OF THE COLON is continuous on the one hand with the transverse colon, and on the other with the descending colon, and is attached to the diaphragm by the *phrenico-colic* fold of peritoneum. It lies in the left hypochondrium in close relation to the spleen.

THE DESCENDING OR LEFT COLON connects the splenic and sigmoid flexures, and occupies the left lumbar region. It is attached by areolar tissue to the left kidney near its outer border, and to the fascia covering the left quadratus lumborum. As low as the level of the 3rd lumbar vertebra it is in relation to the outer border of the quadratus, but from that level to the ilium the quadratus muscle lies behind the descending colon. Owing to its position, and the absence of a peritoneal covering posteriorly, the surgeon opens into this segment of the bowel when he wishes to form an artificial anus.

THE SIGMOID FLEXURE OF THE COLON connects the descending colon with the rectum. It lies in the left iliac fossa, but as the *sigmoid meso-colon*, which forms its peritoneal attachment, is of some length, it is freely movable, and not unfrequently hangs into the pelvis, or even extends across into the right iliac fossa.

THE RECTUM is the terminal segment of the large intestine, and extends from the sigmoid flexure to the orifice of the anus. It occupies the cavity of the pelvis. It commences opposite the left sacro-iliac joint, and passes at first

obliquely downwards and to the right until it reaches the middle line of the sacrum ; secondly, it closely follows the curvature of the sacrum and coccyx, lying in relation to their anterior surface ; thirdly, when it reaches the tip of the coccyx its terminal or third part inclines downwards and backwards for about one inch and a half to the anal orifice. The upper end, or first part of the rectum, is invested by peritoneum, and is attached to the front of the sacrum as far down as its 2nd or 3rd vertebra by the peritoneal fold, termed *meso-rectum*. The second part extends from the 2nd or 3rd sacral vertebra to the tip of the coccyx, is attached to the bone by areolar tissue, and is in relation also to the pelvic fascia. The peritoneum does not form a complete investment for the second part of the rectum ; at first it covers it anteriorly and laterally, lower down only anteriorly, and still lower it leaves it, to be reflected, in the male on the back of the bladder, in the female on the back of the vagina. The third part of the rectum is in relation to the pelvic fascia and the levatores ani muscles, by which parts it is supported and retained in position. In the male the bladder, vesiculæ seminales, and prostate gland are in front of the rectum ; but in the female its anterior surface is in relation to the uterus and vagina, to the latter of which it is intimately connected. The anus opens on the surface of the middle line of the perineum, midway between the two ischial tuberosities, and the skin surrounding the orifice is thin and wrinkled when the opening is closed. Immediately beneath the skin is the *sphincter ani externus muscle*, which forms a thin layer of fasciculi, arranged in a series of ellipses around the orifice. It is attached behind to the tip of the coccyx, surrounds the

opening as it passes forwards, and extends as far as the so-called central tendinous point of the perineum, where it often joins the *acceleratores urinæ* and *transversi perinei* muscles. The sphincter in its normal condition of contraction simply closes the opening, but, under the influence of the will, a more powerful contraction can be induced, so as to resist the entrance of foreign bodies into the rectum.

As the *Levatores ani* muscles are in such intimate relation to the rectum, they may now be described. They form a pair of symmetrically arranged muscles, which descend from the pelvic wall to its perineal outlet. Each arises anteriorly from the back of the body and of the horizontal ramus of the os pubis, posteriorly from the ischial spine, and between these attachments from the pelvic fascia, where it splits into its parietal and rectovesical layers. The muscle passes downwards and inwards to the middle line of the floor of the pelvis to be inserted as follows: most posteriorly into the side of the tip of the coccyx; from the tip of that bone to the anus into the median raphé of the perineum, where it joins its fellow; then into the lower end of the rectum in close relation to the external sphincter; whilst the most anterior fibres descending by the side of the prostate reach the median raphé of the perineum in front of the anus, and blend, on the perineal aspect of the prostate, with the corresponding muscle of the opposite side. Owing to the relation of the anterior or pubic fibres of origin of the levator ani to the prostate gland in the male, they are sometimes named the *levator prostatæ muscle*. In the female the pubic fibres of origin lie in relation to the side

of the vagina. The pair of levator muscles not only assist in forming the pelvic floor, but can draw upwards the organs which lie in relation to it.

On the same plane as, and continuous with the posterior border of each levator ani, is the *Coccygeus muscle*, which arises from the spine of the ischium, and descends as a thin triangular muscle, to be inserted into the side of the lower end of the sacrum and the side and front of the coccyx. It acts as an elevator of the coccyx. The two pairs of coccygei and levatores ani constitute the *pelvic diaphragm*. They and the external sphincter are supplied by the fourth and fifth sacral and the coccygeal nerves.

The large intestine is arranged in the abdominal cavity in the form of an arch, the summit of which is the transverse colon, whilst the cæcum and rectum are the right and left piers. Within the concavity of this arch the coils of the jejunum and ileum are situated. The large intestine is not, except in the rectum, a cylindriciform tube, but is dilated into three parallel and longitudinal rows of sacculi, which rows are divided from each other by longitudinal muscular bands, whilst the sacculi in each row are separated externally by intermediate constrictions. In the rectum the sacculi have disappeared, and the intestine assumes a cylindrical form, but at its lower end it dilates into a reservoir, in which the fæces accumulate prior to being excreted.

At the junction of the large with the small intestine a valvular arrangement, termed the *ileo-cæcal* or *ileo-colic valve*, is found. This valve is due to the peculiar manner in which the ileum joins the cæcum and colon. If these portions of the large intestine be opened into, it will be

seen that the orifice of the ileum is not circular, but elongated in a direction nearly transverse to the long axis of the large intestine.

The opening is bounded by two semi-lunar folds, which project into the large bowel. These folds are the two segments of the valve; one situated above the opening is the *ileo-colic segment*, the other, below the opening, the *ileo-cæcal*. The two segments become continuous with each other at the ends of the elongated opening, and are prolonged for some distance around the inner wall of the large intestine as two prominent ridges, named the *fræna* of the valve. Each segment consists of the mucous and sub-mucous coat, and of the circular layer of the muscular coat of the ileum, which are, as it were, pushed into the canal of the large bowel, at the place of junction, so as to form the prominent folds which have been described. The longitudinal muscular layer and the serous coat of the ileum are prolonged



FIG. 195.—View of the interior of the cæcum and ascending colon, to show the ileo-colic valve. 1, ileum; 2, ascending colon; 3, appendix vermiformis; 4, ileo-colic segment, and 5, ileo-cæcal segment of valve; 6, opening of ileum; 7, mouth of appendix vermiformis.

directly from the ileum to the wall of the large intestine, and do not enter into the segments of the valve. The use of the ileo-cæcal valve is to impede or prevent the reflux of the contents of the large into the small intestine. When the cæcum and colon are distended the fræna of the valve are put on the stretch, and the two segments are approximated, so that the opening is reduced to a mere slit, or even closed, if there is great distension of the bowel. The circular muscular fibres in the segments will doubtless also exercise a sphincter action on the orifice.

Structure of the Large Intestine.

The wall of the large intestine consists in the greater part of its extent of four coats, named from without inwards, serous, muscular, submucous, and mucous coats.

The *serous* or *external coat* derived from the peritoneum, forms a complete investment for the flexures of the colon, the transverse colon, and the first part of the rectum. The cæcum has sometimes a complete serous coat, but more usually, it, together with the ascending and descending colon, have the serous coat only anteriorly and laterally. The second part of the rectum has only a partial serous investment, and the third part has no serous coat. Numerous pedunculated processes invested by the serous membrane, and containing lobules of fat, named *appendices epiploicæ*, are attached to the large intestine. The serous coat is loosely united to the subjacent muscular coat by areolar tissue, which is sometimes called the *subserous coat*.

The *muscular coat* consists of non-striped fibres arranged

in two layers from without inwards. The outer layer consists of longitudinal fasciculi, which are not as a rule distributed uniformly in the wall, but in the cœcum and colon are collected into three longitudinal bands, which start from the cœcum, where it is joined by the appendix vermiformis, and extend along the colon to the rectum. One band extends along the meso-colic or attached aspect of the bowel, another along the anterior aspect, whilst the third is situated on the inner aspect of the ascending and descending colon, and the under aspect of the transverse colon. As these bands are not so long as the colon itself, they occasion the puckering or constrictions in the wall which separate the sacculi, so that when the bands are cut through the sacculi disappear. The colon then becomes more elongated and cylindriciform.

In the appendix vermiformis the longitudinal layer is not collected into bands, but arranged uniformly along the wall. In the rectum, also, the longitudinal layer is spread uniformly along the wall, and forms a well-defined red-coloured layer. Slender fasciculi have been described as passing from this layer to the adjacent pelvic fascia, and to the subcutaneous tissue about the anus, and Luschka has traced some bundles into the anterior sacro-coccygeal ligament.

The inner layer of the muscular coat consists of *circular* fasciculi distributed around the wall of the large intestine. In the rectum this layer increases in thickness, and in proximity to the anus forms a circular muscle, the *sphincter ani internus*, which is a strong band, about half an inch broad, around the lower end of the rectum. In the large, as in the small intestine, the muscular coat

occasions the peristaltic movements, and its increased thickness in the rectum is for the purpose of expelling the fæces.

The *submucous coat* has similar relations and structure to the corresponding coat in the small intestine.

The *mucous, or internal coat*, is not thrown into valvulæ conniventes, but presents a series of well-marked permanent ridges, lying transversely or somewhat obliquely to the long axis of the gut, and corresponding internally to the constrictions, which, on the outer surface of the colon, separate the sacculi from each other (fig. 195). These ridges are also found in the rectum, though in diminished numbers. Of the rectal folds, three have been especially described by Houston—one, the lowest, is about $1\frac{1}{2}$ inch from the anus; another, the highest, is near the sacral promontory, whilst the third is somewhere intermediate. The transverse folds are formed not only of the mucous and submucous coats, but of the circular layer of the muscular coat. Near the anal orifice the mucous coat is folded longitudinally, and forms the *columnæ recti* of Morgagni. The mucous membrane of the large intestine is covered by a layer of columnar epithelium. It is devoid of villi, and consists of a glandular and a muscular layer. The secreting glands of the glandular layer have the form and structure of the Lieberkühnian glands of the small intestine (fig. 189, 191); they open on the free surface of the mucous coat, and, owing to the absence of villi, their mouths are more closely set together than is the case with the corresponding glands in the small intestine; the tubular glands are separated by a retiform tissue containing lymphoid corpuscles. Solitary glands, similar to those

in the small intestine, are also present; but no Peyer's patches. The muscularis mucosæ resembles generally that of the small intestine.

Of the *blood-vessels* of the large intestine, the arteries are principally derived from the colic branches of the superior mesenteric and the several branches of the inferior mesenteric artery; but the lower end of the rectum receives the middle hæmorrhoidal branches of the internal iliac, and the inferior hæmorrhoidal branches of the pudic. The veins which correspond to these arteries for the most part join the superior and inferior mesenteric veins, and are consequently rootlets of the portal vein. But the veins which belong to the middle and inferior hæmorrhoidal arteries form a plexus about the anal orifice, which partly joins the superior hæmorrhoidal vein, and through it the portal vein, and is partly connected through the middle and inferior hæmorrhoidal veins with the internal iliac vein, and through it with the inferior vena cava. The veins about the anus are very apt to become varicose, and to form the excrescences termed hæmorrhoids or piles. The *lymph vessels* are arranged as in the small intestine, except that they are not prolonged into villi. Nervous plexuses with ganglion cells are found in both the muscular and submucous coats. They proceed from the superior and inferior mesenteric plexuses, but the rectum receives branches from the hypogastric plexus, and from the third and fourth sacral spinal nerves.

THE LIVER.

The Liver is the biggest of the abdominal viscera, and the largest gland in the body. It is the organ in which the secretion of bile takes place, and is the chief seat in the body of the formation of glycogen, a substance like dextrine, which readily undergoes conversion into sugar. It lies in the costal zone of the abdomen, fills up the greater part of the right hypochondrium, and extends, through the epigastrium, into the left hypochondrium. In its long or transverse diameter it averages about 12 inches, in its antero-posterior diameter about 6 inches, in the vertical diameter of its thickest part about 3 inches. Relatively to the size of the body the liver is bigger and heavier in the foetus than in the adult; soon after birth the relative weight declines, and that of the left lobe diminishes much more rapidly than the right lobe. Frerichs states that the relative weight of the healthy liver fluctuates in adults between $\frac{1}{24}$ th and $\frac{1}{40}$ th that of the body, and the absolute weight varies from 1·8 to 4·6 pounds avoird. During the digestion of the food the liver increases both in size and weight, partly from the greater quantity of blood flowing through it, and partly from the new material in the secreting cells; whilst after a long fast it becomes smaller and lighter.

For descriptive purposes the liver may be regarded as having two surfaces, two borders, and two extremities. The *superior* or *diaphragmatic surface* is smooth and convex, and in close contact with the under surface of the vault of the right half of the diaphragm, with its central

tendon, and with a portion of the left half of the muscle, also with the anterior abdominal wall in the upper part of the epigastrium. It is attached to the diaphragm and epigastric wall of the abdomen by a fold of the peritoneum, called the *falciform* or *suspensory ligament*, which extends along the upper surface from the anterior to the posterior border of the liver, and marks the division into a large right and a small left lobe. From the close relation of this surface of the liver to the diaphragm it follows the movements of that muscle, being depressed during inspiration, elevated during expiration. The highest part of the surface of the liver lies at the end of an expiration opposite the 4th right intercostal space, a little to the inner side of the right nipple, from which spot it rapidly slopes downwards to the right about as low as the 11th right rib, whilst it inclines much more gradually to the left almost on a line with the junction of the ensiform cartilage with the meso-sternum. The 5th, 6th, 7th, 8th, 9th, and 10th ribs, separated by the diaphragm, arch superficially to its right lobe, whilst the left lobe is arched over by the cartilages of the 6th, 7th, and 8th ribs. The summit of the right lobe is in relation, the diaphragm intervening, with the base of the right lung; that of the left lobe with the heart, pericardium, and a portion of the base of the left lung. The upper surface of the liver is sometimes marked by furrows extending in the antero-posterior direction, which, when the organ is *in situ*, are occupied by folds of the diaphragm. These depressions have usually been ascribed to tight lacing, the pressure of the stays being supposed to have forced the ribs and diaphragm into the liver. But as I have seen these furrows almost as fre-

quently in men as in women, I regard them, and the coincident depression of the ribs, as congenital, and not as artificially produced.

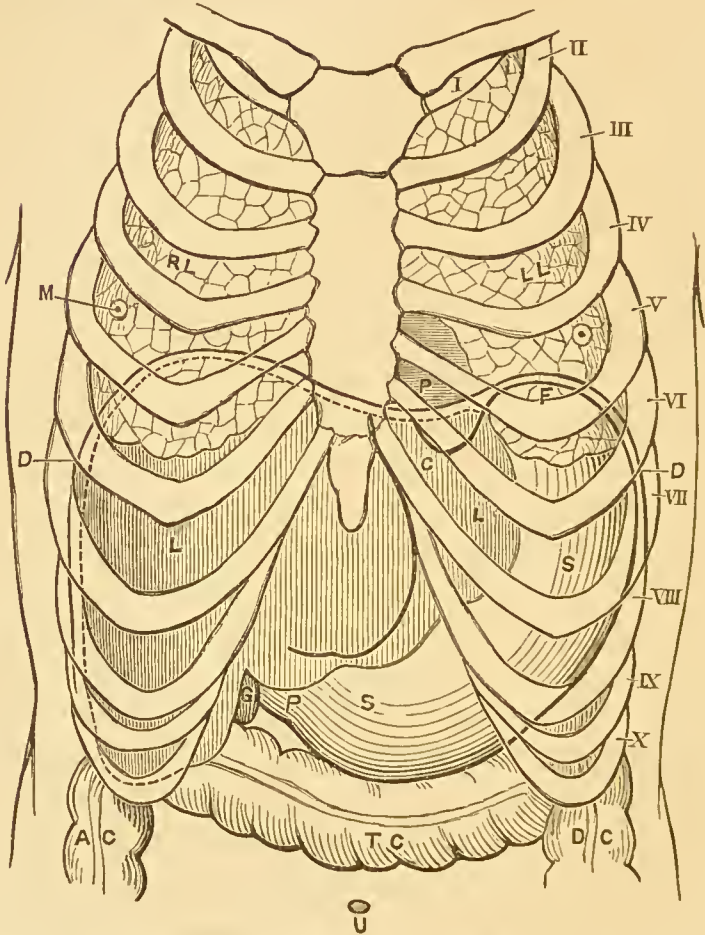


FIG. 196.—The Lungs and their relations to the Diaphragm, Liver, and Stomach. II, to X, second to tenth ribs; DD, diaphragm; RL, right, and LL, left lung; P, pericardium; S, S, stomach; F is placed superficial to its fundus; P, its pylorus; C is over the cardiac orifice; L, L, the liver; G, gall bladder; AC, ascending, TC, transverse, and DC, descending colon; U, umbilicus; M, right nipple. Modified from Lushka.

The *posterior* or *vertebral border* of the liver is thick, and rounded at its right extremity, but comparatively thin at

the left. It is attached by areolar tissue to the diaphragm, and a fold of peritoneum called the *coronary ligament*, passes from it to the under surface of that muscle. The coronary ligament expands at its extremities into the *right* and *left lateral ligaments*, and becomes continuous with the posterior border of the falciform ligament opposite a slight depression which marks the separation of the right from the left lobe of the liver. The posterior border is notched for the lodgment of the inferior vena cava.

The *anterior border* of the liver is unattached, thin, and attenuated, and is marked by a deep notch, opposite the anterior edge of the falciform ligament, which lodges the *round ligament* of the liver. This notch marks the separation of the right from the left lobe. To the right of this round ligament is a shallow notch in the anterior border, at which the fundus of the gall bladder may be usually seen to project; at this spot the liver overlaps the ascending part of the duodenum.

Of the two *extremities* of the liver the *right* is thick and massive, and lies deep in the right hypochondrium, in contact with the diaphragm; the *left* is thin and attenuated, and overlaps the œsophageal opening and fundus of the stomach.

The *inferior* or *visceral surface* of the liver is much more complex in form than the upper.

The *longitudinal* or *umbilical fissure*, continuous with the notch in the anterior border of the liver, and much nearer to the left than the right extremity of the gland, divides it into a large right and a small left lobe. In the anterior part of the fissure the *round ligament* formed by the obliteration of the *umbilical vein* of the fœtus is lodged;

whilst the posterior part contains a slender fibrous cord formed by the obliteration of a vein of the fœtus, named *ductus venosus*. The longitudinal fissure is often bridged across by a band of liver substance called *pons hepatis*. The under surface of the left lobe is smooth, and overlaps the anterior surface of the stomach. The under surface of

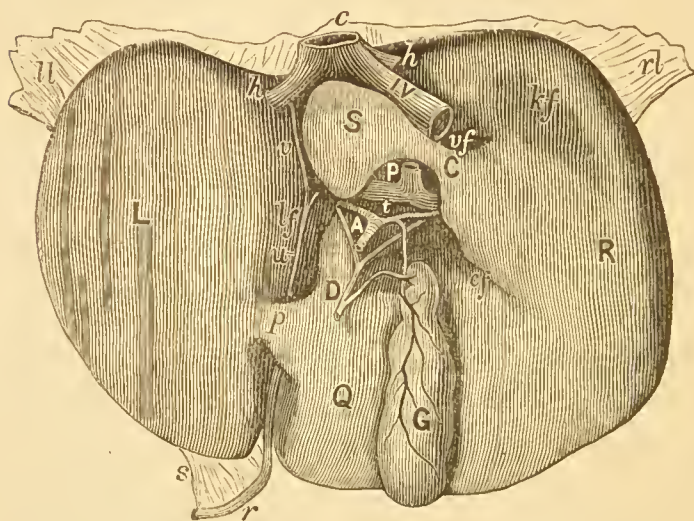


FIG. 197.—Under surface of the Liver. R, right, L, left lobe; Q, lobus quadratus; S, lobus Spigelii; C, lobus caudatus; p, pons hepatis; lf, longitudinal fissure; t, transverse fissure; cf, caudate fissure; vf, fossa for vena cava; kf, fossa for right kidney; G, gall bladder in its fossa; u, obliterated umbilical vein; v, obliterated ductus venosus; IV, inferior vena cava; h, h, hepatic veins; p, portal vein; A, hepatic artery; D, bile duct; c, coronary ligament; ll and rl, left and right lateral ligaments; S, suspensory ligament; r, round ligament.

the right lobe is divided into smaller lobes by fissures and fossæ. Starting from about the middle of the longitudinal fissure is the *portal* or *transverse fissure*, which extends for from three to four inches across the under surface of the right lobe. It is the gate (*porta*) of the liver, the *hilus* or fissure of entrance into the organ of the portal vein,

hepatic artery, hepatic duct, hepatic nerves, and lymphatics. A short distance to the right of that part of the longitudinal fissure in which the round ligament lies, is the *fossa for the gall bladder*, which is a depression on the under surface of the right lobe extending from the anterior border to the transverse fissure : in it the gall bladder lies. Extending somewhat obliquely from the posterior border of the liver, towards the transverse fissure, is a deep *fossa for the inferior vena cava*, which lodges this great vein before it pierces the diaphragm. Sometimes the vena cava is bridged across by a prolongation of the liver substance. Opening into the vena cava as it lies in this fossa are the trunks of the large hepatic veins from the substance of the liver. A portion of liver substance, which is bounded by the gall bladder, the longitudinal fissure, the transverse fissure, and the anterior border, forms a four-sided lobe called *lobus quadratus*. Another portion, bounded by the transverse fissure, the posterior border, the vena cava, and the longitudinal fissure, is the *lobus Spigelii*. A thin prolongation of liver substance continuous with the lobus Spigelii, and running obliquely between the fossa for the inferior cava and the transverse fissure, is the *lobus caudatus*. The lobus caudatus is rudimentary in the human liver, but, as W. H. Flower has pointed out, attains a considerable magnitude in many mammals. He has named the fissure, which separates it from the adjacent part of the right lobe, the *fissure of the caudate lobe*. To the right of the fossæ for the gall bladder and inferior cava are two shallow depressions on the under surface of the right lobe ; the more anterior marks the position of the hepatic flexure of the colon, the more posterior, the upper end of the right

kidney and supra-renal capsule. As the liver is a solid organ, the sound which is elicited by percussing the wall of the abdomen superficial to it is a dull sound. But as the liver has three resonant structures in relation to it, viz., the lung above, and the hepatic flexure of the colon and the stomach below, the dull sound is necessarily modified in the regions occupied by those organs. As the heart is in relation to a portion of the upper surface of the liver, the line of demarcation in that locality between the two organs is with difficulty discriminated by percussion.

Structure of the Liver.

The liver is a solid organ, of a brownish-red colour. It is composed of the ramifications of the portal vein, of the portal capillaries, the hepatic vein, the hepatic artery, the hepatic duct, of secreting cells, nerves, and lymphatics. These several structures are bound together by connective tissue, and the organ is invested by the peritoneum. The liver possesses two coats, a serous and a fibrous.

The *serous* or *external coat* is a part of the peritoneal membrane, and forms an almost complete investment for the liver. Where the gall bladder and inferior cava lie in contact with the under surface it is prolonged over those bodies; it is reflected from the transverse fissure as the gastro-hepatic omentum, and from the upper surface and the posterior border as the falciform, coronary, and right and left lateral ligaments.

The *fibrous coat*, or *tunica propria*, is immediately subjacent to the serous coat, and is so closely adherent to it as

to be separated from it with difficulty; but along the lines of reflection of the ligaments from the liver, at the transverse fissure, and at the fossæ for the gall bladder and inferior cava, it can be readily recognised as a definite fibrous membrane. When carefully raised from the liver delicate processes of areolar tissue may be seen to pass from its deep surface into the substance of the organ. At the transverse fissure it is prolonged into the liver as a very distinct sheath, enveloping the portal vein, hepatic artery, hepatic duct, nerves, and lymphatics. This sheath is named the *capsule of Glisson*, and is prolonged throughout the substance of the organ, along the ramifications of the portal vein, and the structures that accompany it.

Lobules of the Liver.—To the naked eye the substance of the liver does not present a homogeneous aspect, but is mottled, and mapped out into multitudes of small areas or lobules,—the *hepatic lobules* or *leaflets*. The lobules of the liver are irregular polygons, and vary in size from $\frac{1}{20}$ th to $\frac{3}{20}$ th of an inch. In man and the mammalia generally, the lobules are imperfectly separated from each other by the interlobular vessels and duct, and a scarcely appreciable quantity of areolar connective tissue. In the pig, as is well known, each lobule is circum-

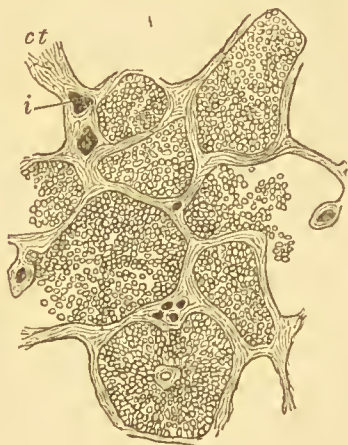


FIG. 198.—Section through the liver of a Camel, to show the lobules. *ct*, capsule of connective tissue; *i*, divided interlobular vein. $\times 10$.

scribed by a definite capsule of connective tissue, and the capsules of adjacent lobules blend with each other. In the camel the observations of Goodsir showed that the capsules of connective tissue were thicker and more distinct than in the pig. In the polar bear, Johannes Müller has described the lobules as distinct and easily separable from each other; and Hyrtl has observed a similar appearance in the liver of the South American rodent, *Octodon Cumingii*. The capsule of connective tissue is continuous with Glisson's capsule, which invests the interlobular vessels, and, in the case of the lobules lying next the surface of the liver,

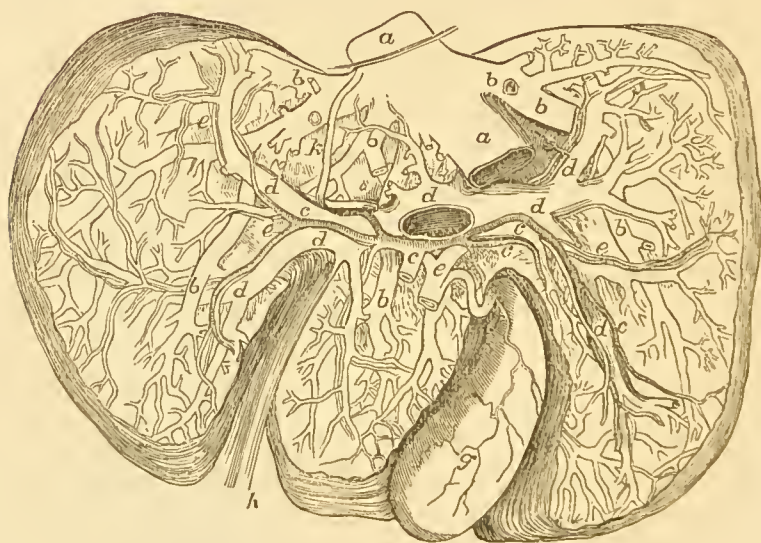


FIG. 199.—The under surface of the Liver, dissected to show the ramifications of the vessels in its substance. *a*, inferior vena cava; *bb*, hepatic veins; *c, c*, hepatic artery; *dd*, portal vein; *e, e*, hepatic duct; *g*, gall bladder; *h*, round ligament.

with the delicate processes of the fibrous coat which pass into the substance of the organ.'

As a lobule of the liver is a liver in miniature, and as the structure of the entire liver is the sum of the structure of its constituent lobules, it will be necessary to examine with care the constituent parts of a lobule, and the arrangement of the vessels, duct, and nerves which pass to and from it. A hepatic lobule is composed of blood-vessels, secreting cells, and bile ducts, with perhaps nerves and lymphatics. The blood-vessels will first be considered. The liver receives its supply of blood through two vessels, the portal vein and hepatic artery, and the blood brought by both these vessels leaves the liver through the large hepatic vein.

The *portal vein* conveys to the liver the venous blood from the stomach, spleen, pancreas, gall bladder, and small and large intestine. It ascends to the transverse fissure, and before it enters the liver divides into two branches, one for the right and one for the left lobe. In its course, within the liver, the portal vein divides and subdivides after the manner of an artery. It is closely accompanied by the hepatic artery and duct, and, along with them, is invested by the fibrous sheath, called Glisson's capsule. The terminal branches of the portal vein run between the lobules, and are named, from their position, the *interlobular* branches. The interlobular branches lie around the circumference of a lobule, and anastomose with each other. They partly terminate directly in a capillary network situated within the lobule, and partly give off fine branches, which enter the lobule before they end in the capillary network. The *intralobular capillaries* form a close network, which converges from the periphery of the lobule, where they spring from the interlobular

branches of the portal vein, to the centre of the lobule,



FIG. 200.—Transverse section through the hepatic Lobules. *i, i, i*, interlobular veins ending in the intralobular capillaries. *c, c*, central veins joined by the intralobular capillaries. At *a, a*, the capillaries of one lobule communicate with those adjacent to it. From an injection by T. A. Carter.

where they terminate in the *intra-lobular* or *central vein*, one of the rootlets of the hepatic vein. In man, where the lobules are not separated from each other by a distinct capsule, the capillaries of one lobule to some ex-

tent communicate with those of adjacent lobules.

The *hepatic artery*, a branch of the cœliac axis, closely accompanies, as already stated, the portal vein, and divides into two branches, for the right and left lobes. It enters the transverse fissure and ramifies, along with the portal vein, through the substance of the liver. It is the nutrient artery of the liver, and gives off three series of branches: *a*, *vaginal branches*, which are distributed to the walls of the portal vein, the hepatic duct, and to Glisson's capsule, probably also to the wall of the hepatic vein. They end in a capillary network in these structures, from which *vaginal veins* arise that terminate in the portal vein. *b*, *capsular branches*, which are distributed to the fibrous coat of the liver and end in a capillary network, from which arise *capsular veins* that join the portal vein. The capsular branches anastomose with the diaphragmatic arterics, in the areolar tissue which attaches the posterior border of the liver to the diaphragm, and sundry offshoots which pass

between the layers of the suspensory ligament, anastomose with the epigastric branch of the internal mammary artery. *c*, *interlobular branches* of the hepatic artery lie along with the interlobular branches of the portal vein, and end in the capillary network within the lobules.

The *hepatic vein* arises within the substance of the liver from the intra-lobular capillaries. In the centre of each lobule is the *intra-lobular* or *central vein*. It traverses the axis of the lobule, and leaves it to join a small vein running immediately under the bases of adjacent lobules, which, from its position, is named the *sub-lobular vein*. Adjacent sub-lobular veins then join together, and form larger vessels which are the *trunks* of

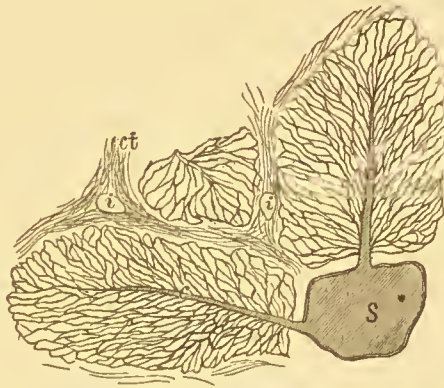


FIG. 201.—Vertical section through two hepatic Lobules of a pig. *c*, *c*, central veins receiving the intra-lobular capillaries. *s*, sub-lobular vein. *ct*, interlobular connective tissue forming the capsules of the lobules; *i*, *i*, interlobular veins. From an injection by T. A. Carter.

the *hepatic vein*, or the *hepatic venous canals*. These trunks run towards the posterior border of the liver, and open into the inferior vena cava. The sub-lobular veins and hepatic venous trunks differ from the branches of the portal vein in the following particulars:—They are not accompanied by other vessels; they are not invested by Glisson's capsule, and are more or less closely adherent to the surrounding lobules; they gape, and do not collapse when the liver is cut through; their coats are so thin that

the lobules can be seen through them; they have no relation to the transverse fissure.

From this description of the vascular arrangements within the liver, it will be seen that the intra-lobular capillaries are continuous with three vascular trunks, two which carry blood to them, the portal vein and the hepatic artery; one which conveys the blood away from them, the hepatic vein. The communication in each case is so free that the capillaries can be artificially injected from any one of these vessels.

The *secreting cells* of the liver, *hepatic cells*, form the proper parenchyma of the organ. They are situated within the lobules, and occupy the spaces of the capillary network. The cells vary in diameter from $\frac{1}{840}$ th to $\frac{1}{1030}$ th inch; they have the form of irregular polyhedrons, with from four to seven sides, and with the angles sometimes sharp, at others rounded. They do not appear to possess definite walls, but have a distinct nucleus. The cell protoplasm is granular, and usually contains fat drops and yellow particles, apparently bile pigment. Colourless gra-

nules, believed to be glycogenic, are also infiltrated through the protoplasm. Amœboid movements have been observed to take place in these cells, when isolated from each other. W. Krause states that fusiform cells sometimes lie between the polyhedral cells. The general arrange-

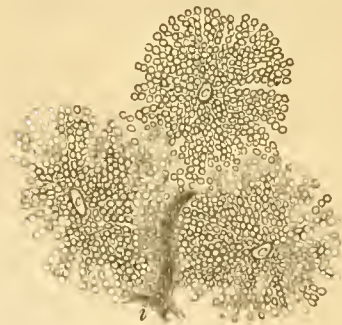


FIG. 202.—Transverse section through Lobules of human liver to show the columns of secreting cells. c.c, central veins; i, interlobular vein with a fine sheath of connective tissue. $\times 10$.

ment of the cells is in rows or columns, and when sections are made through a lobule, transverse to the long axis of the central vein, the columns of cells are seen to converge from the periphery to the centre of the lobule, and to form a network.

By many observers the cells are regarded as in contact with the intra-lobular capillaries, without the intervention of an intermediate membrane.

By others, and more especially by Lionel Beale, the secreting cells are regarded as enclosed in a tubular network, the wall of which is formed by a basement membrane. Beale states that the diameter of the network is usually about $\frac{1}{1000}$ th of an inch in most mammals. According to this view, the cells are not in direct contact with the capillary blood-vessels, but separated from them by the basement membrane. In some parts of the lobule Beale has been able to demonstrate the basement membrane as distinct from the wall of the capillaries, but usually they are incorporated together. At the periphery of the lobule the membrane becomes continuous with the wall of the interlobular duct. I have seen in the liver of the camel delicate bars of connective tissue, prolonged from the capsule of the lobule between the columns of secreting cells, so as to form a sustentacular tissue quite distinct from the network of blood capillaries.



FIG. 203.—Portion of the lobule of a camel's liver. *ct*, capsular connective tissue; *ct'*, intralobular prolongations of the capsule between the columns of cells. $\times 300$.

The *hepatic*, or *bile duct*, is the tube that conveys the bile out of the liver. It leaves the transverse fissure as two branches, one from the right, another from the left lobe, which almost immediately unite at an acute angle. As already stated, it closely accompanies within the liver the ramifications of the portal vein and hepatic artery, and its terminal branches pass between the lobules to form the *interlobular branches* of the duct. If the hepatic duct be injected, not only does the injection fill the interlobular ducts, but it flows into a set of excessively minute passages within the lobules themselves. These passages are arranged so as to form a polygonal network, which may appropriately be called the *intralobular biliary network*. This network has a most intimate relation to the polyhedral hepatic cells, for the passages lie between the flattened sides of adjacent cells, so that each cell is enclosed in a mesh of the network.

The German observers, who first directed attention to these passages, named them *bile-capillaries*, and Macgillivray, Frey, and Eberth supposed that they possessed an independent wall, distinct from the hepatic cells between which they are situated. But it is doubtful if such a wall exists, and it seems much more probable that they are merely intercellular passages bounded by the protoplasm of the hepatic cells.

The intra-lobular biliary network differs from the intra-lobular blood capillary network, not only in the character of the fluid conveyed, but in other important particulars. The bile passages have a transverse diameter of about $\frac{1}{10}$ th that of the blood capillaries: the passages are in relation to the sides of the cells, the blood capillaries to

their angles, so that the two systems of networks are not in contact with each other, but are separated by intervening hepatic cell substance; the passages have not, in all probability, an independent wall, such as is possessed by the blood capillaries.

As these passages can be injected from the hepatic duct, and as they convey bile from the interior of the lobule into the duct, it is obvious that they must be continuous with the lumen of the interlobular branches of the duct, at the periphery of the lobules. The wall of an interlobular duct consists of a *membrana propria*, lined by columnar epithelium. From this duct fine branches enter the periphery of the lobule, and the epithelial lining abuts on and assumes the character of the rows of hepatic cells, whilst the intercellular passages of the biliary network become continuous with the lumen of the duct.

The wall of the larger bile ducts is formed of a fibro-elastic tissue, with a proportion of non-striped muscular fibre: it is lined by a columnar epithelium. Opening into the larger ducts are numerous orifices, which communicate with branched cœcal tubes and follicles, situated within and clustered around the walls of the larger ducts, often in considerable numbers. Some of these appendages to the duct doubtless serve as glands for the secretion of mucus, but others are probably, as Beale supposed, mere diverticula of the duct, in which the bile may be temporarily retained, as in the gall bladder.

The hepatic duct also gives origin to some *aberrant ducts*, which were described by Kiernan and Henle as passing into the left lateral ligament of the liver, and into the fibrous bands, which sometimes bridge over the

fossa for the vena cava and the fissure for the umbilical vein. They anastomose freely with each other in these localities, and have blind terminations; they are not surrounded by hepatic lobules. They are lined by columnar epithelium.

The *lymphatics* of the liver form a superficial and a deep set. The superficial set ramifies beneath the serous coat, where it forms a network. Each capsular branch of the hepatic artery is, according to T. A. Carter, accompanied by a pair of lymphatics, which are connected together at intervals by short transverse branches, so that the artery is more, or less ensheathed by lymphatics. The deep lymphatics accompany the portal vein and hepatic artery as far as the intervals between the lobules, where they form *interlobular lymphatics*, which, like the corresponding branches of the portal vein, run around the lobule. Carter has traced into the lobule towards its centre minute branches of the interlobular lymphatics; Macgillavry considers that the intra-lobular capillaries are surrounded by lymph spaces; A. Budge has injected lymph-vessels in the wall of the central vein of the hepatic lobules, and Kölliker has observed lymphatics surrounding the hepatic vein. Kisselew has described lymph-follicles in relation to the interlobular lymphatics of the pig.

The *nerves* of the liver arise from the cœliac plexus of the sympathetic and from the left pneumogastric. They accompany the portal vessels in their distribution, and supply the muscular coats of the vessels. According to Pflüger, nerves may be traced to the secreting cells within the lobules.

The *obliterated umbilical vein*, to which reference has

been made in the description of the round ligament of the liver, is an important vessel in the foetus. It conveys the blood from the placenta, enters the abdominal cavity at the umbilicus, and ascends to the longitudinal fissure on the under surface of the liver. Here it divides into three branches; one joins the portal vein, and conveys the blood through that vessel into the intra-lobular capillaries and hepatic vein; another enters the liver, and divides into branches, which terminate in the intra-lobular capillaries; the third continues in the longitudinal fissure under the name of *ductus venosus*, and joins directly the inferior vena cava. The blood of the umbilical vein ultimately reaches, therefore, the inferior cava, either directly or by passing through the hepatic circulation. When the umbilical cord is tied after the birth of the child, the connection with the placenta is severed, and the umbilical vein and ductus venosus shrivel up into fibrous cords.

The GALL BLADDER is a reservoir for the bile, situated in a fossa on the under surface of the right lobe of the liver, and in a notch in its anterior border (fig. 197). It is pyriform in shape, its larger end, or fundus, projects beyond the anterior border; its opposite end, or neck, gives origin to the *cystic duct*, which is directed towards the transverse fissure; after a course of $1\frac{1}{2}$ inch, it joins the hepatic duct, and forms the common bile duct, *ductus communis choledochus*. At its neck, the gall bladder bends on itself in a sigmoid curve. The gall bladder is three or four inches long, and can hold from one to two oz. of bile. It is attached to the liver partly by areolar tissue, and partly by the peritoneum, which is reflected over its free surface.

Structure.—In addition to its partial *serous coat*, the gall bladder has a fibrous and mucous coat. The *fibrous coat* consists of interlacing bands of connective tissue, with which non-striped muscular fibres are sparingly intermingled. The *mucous membrane* lining the gall bladder is deeply bile-stained, and presents on its free surface an alveolar appearance, due to the presence of multitudes of minute folds, which form a reticulum with intermediate depressions. This surface is covered by columnar epithelium. The mucous lining of both the neck of the gall bladder and cystic duct is thrown into folds, which in the duct have an oblique direction, and form the spiral valve. Racemose glands, for the secretion of mucus, occur in the wall of the gall bladder, cystic duct, and common bile duct. The gall bladder is supplied with blood by the cystic branch of the hepatic artery. It receives lymphatics and nerves continuous with those which belong to the liver.

The *Common Bile Duct*, formed by the junction of the cystic and hepatic ducts, is about 3 inches long, and conveys the bile into the duodenum. It lies in the gastro-hepatic omentum between its two layers, having the hepatic artery to its left, and the portal vein behind it. It then inclines behind the duodenum to the inner side of its descending part, where it comes into relation with the pancreatic duct. The two ducts then run together in an oblique direction through the wall of the duodenum, and open on the summit of a papilla, by a common orifice, about the junction of the descending and transverse portions of the duodenum.

THE PANCREAS.

The Pancreas is an elongated gland which lies in relation to the posterior wall of the abdomen, in front of the first lumbar vertebra, and extends obliquely from the right lumbar region through the epigastrium into the left hypochondriac region. It is from 6 to 8 inches long, and whilst its dilated right extremity, or *head*, occupies the horse-shoe curve of the duodenum, and is attached by areolar tissue to the descending and transverse portions, its attenuated left extremity, or *tail*, is in relation to the spleen. Anterior to the pancreas is the pyloric end of the stomach and a portion of the posterior surface of that organ, but between the stomach and pancreas is the lesser cavity of the peritoneum, and the anterior surface of the pancreas is covered by the layer of peritoneum, which forms the posterior boundary of that cavity. It is attached behind by areolar tissue to the crura of the diaphragm, the splenic and superior mesenteric vessels, the portal vein, the aorta, inferior vena cava, left kidney, and supra-renal capsule. A prolongation of the gland, named the *accessory* or *lesser pancreas*, usually surrounds the superior mesenteric artery at its origin.

Structure.—The pancreas is one of the compound racemose glands, and resembles generally in structure the mucous and salivary glands of the mouth and the glands of Brunner (fig. 191). It is sometimes called the abdominal salivary gland, and its secretion flows into the duodenum, and assists in the process of chylification. It has a yellowish creamy colour, and is divided

into distinct lobules by septa of connective tissue. The excretory duct, or *duct of Wirsung*, is completely surrounded by the lobules, and extends from the tail to the head of the gland, receiving in its passage the numerous secondary ducts, and increasing gradually in size. It leaves the head of the gland, comes into relation with the common bile duct, and with it pierces obliquely the posterior wall of the descending part of the duodenum, to open by a common orifice about the junction of the descending and transverse portions. Sometimes the duct from the accessory part of the pancreas opens independently into the duodenum, a little above the common hepatico-pancreatic orifice. The finest ducts within the gland terminate in the *acini*, or *gland vesicles* of the lobules. These acini contain the secreting cells, which have a somewhat cubical form. Minute channels or intercellular passages have been described by Saviotti, between the secreting cells, similar to those already referred to in the acini of the salivary glands. The ducts are lined by a columnar epithelium, and mucous glands are situated in the mucous membrane lining the duct of Wirsung. The pancreas receives its supply of blood from the pancreatic branches of the splenic artery, the inferior pancreatico-duodenal of the superior mesenteric, and the superior pancreatico-duodenal of the gastro-duodenal of the hepatic. Its veins join the splenic and superior mesenteric veins, and through them contribute to the formation of the portal vein. Its blood capillaries are abundantly distributed on the walls of the gland vesicles. Lymph vessels are found in the connective tissue between the lobules. The nerves are derived from the solar

plexus, and accompany the arteries ; they are believed by Pflüger to have a similar mode of termination to that described by him in the salivary glands (p. 658).

THE TEETH.

The Teeth are calcified organs developed in connection with the mucous membrane of the mouth. Their primary use is that of biting and grinding the food ; but in man they serve as aids to speech, and in many animals act as instruments of offence and defence.

Arrangement and Form of the Teeth.

Teeth are present in the greater number of the mammalia, in which class they are implanted in sockets in the alveolar arches of the bones of the upper and lower jaws, and form only a single row in each arch. In a few mammals, as the toothed whales and the sloths, only one generation of teeth is produced, and when these drop out, they are not replaced by successors ; these animals are called Monophyodont. In the majority of the mammalia, however, there are two generations of teeth ; a temporary or milk set, which are deciduous, and are replaced by a permanent or adult set ; these animals are called Diphyodont. But in speaking of two generations of teeth it is not to be supposed that all the teeth in the adult jaw have had temporary predecessors, for the molar or back teeth have only a single generation. A few mammals, as the toothed whales, have the teeth uniform in size, shape, and structure, and are named Homodont ;

but, in the majority of the mammalia, the teeth in the same jaw vary in size, form, and structure, and are therefore called Heterodont. In

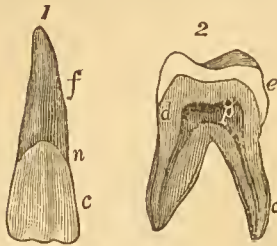


FIG. 204.—1, A human upper incisor Tooth. *c*, the crown; *n*, neck; *f*, the fang. 2, a section through a molar tooth; *e*, cap of enamel; *c*, cement; *d*, dentine; *p*, pulp cavity.

every Heterodont mammal, possessing a complete dentition, four groups of teeth are found, which are named incisor, canine, premolar, and molar teeth. Each of these teeth possesses a *crown*, which projects into the cavity of the mouth, and a *fang* lodged

in the socket in the jaw; at the junction of the crown and fang there is usually a constriction named the *neck* of the tooth.

In Man the dentition is Diphyodont and Heterodont. The single row of teeth in each alveolar arch of the human jaw is characterised by the crowns of the teeth being of almost equal length, and by the absence of any great interspace, or *diastema*, between the different teeth, or of irregularities in the size of the interspaces, so that the teeth form an unbroken series in each jaw. The span of the upper dental arch is slightly bigger than that of the lower, so that the lower incisors fit within the upper, and the lower molars, being inclined obliquely upwards and inwards, are somewhat overlapped by the upper molars. The upper and lower dental arches terminate behind in line with each other, and the teeth are equal in number in the two jaws.

Man possesses 32 teeth in his permanent dentition, arranged in four groups, viz.—8 incisors, 4 canines, 8

premolars or bicuspid, and 12 molars. The number and arrangement of the teeth in the two jaws is expressed in the following formula :—

Formula of Permanent Dentition.

$$\begin{array}{cccc|cccc} \text{m.} & \text{pm.} & \text{c.} & \text{in.} & \text{in.} & \text{c.} & \text{pm.} & \text{m.} \\ 3 & 2 & 1 & 2 & 2 & 1 & 2 & 3 \\ \hline 3 & 2 & 1 & 2 & 2 & 1 & 2 & 3 \end{array} = 32.$$

Man possesses only 20 teeth in his milk or temporary dentition, and their arrangement is expressed in the following formula :—

Formula of Temporary Dentition.

$$\begin{array}{ccc|ccc} \text{m.} & \text{c.} & \text{in.} & \text{in.} & \text{c.} & \text{m.} \\ 2 & 1 & 2 & 2 & 1 & 2 \\ \hline 2 & 1 & 2 & 2 & 1 & 2 \end{array} = 20.$$

If the temporary and permanent formulæ be compared with each other, it will be seen that, while the incisors and canine teeth correspond in numbers in both dentitions, in the temporary dentition there is an absence of premolars, and the molar teeth are only 8, instead of 12 in number.

The characters of the permanent teeth will now be considered.

The *Incisor Teeth*, eight in number, are lodged in the front of the jaws, two on each side of the mesial plane. The upper incisors project downwards and forwards, the lower are directed almost vertically upwards. The oblique direction of the upper incisors in the Negroes, Caffres,

and Australians adds to the prognathic form of the face possessed by these races. The central pair of upper incisors are larger than the lateral: whilst the lateral pair of lower incisors are larger than the central pair, which are the smallest incisor teeth. The crowns of the incisor teeth are chisel-shaped, and adapted for biting and cutting the food; the anterior or labial surface is convex, the posterior, palatal, or lingual surface is concave. When the crown is first erupted the cutting edge is minutely serrated, but the serrations soon wear down by use. The fangs are long and single; being in the upper incisors round and fusiform, in the lower laterally compressed, and sometimes marked by a longitudinal groove. Although the human incisors are, as the name implies, cutting, chisel-shaped teeth, in many mammals the incisors are greatly modified in form, as for example in the tusks of the elephant. The determination of the incisor teeth does not depend, therefore, on their form, but on their position in the jaws. The name incisor is given to the teeth situated in the pre-maxillary portion of the upper jaw, and in the anterior end of the lower jaw, whatever their shape may be.

The *Canine* or *Unicuspid Teeth*, four in number, one on each side of the mesial plane of each jaw, are placed next the lateral incisors. They are bigger than the incisor teeth, and the upper canines, which are sometimes called the cyc-teeth, are larger than the lower; the fangs of the upper canines are lodged in deep sockets in the superior maxillæ, which extend towards the floor of each orbit. The crowns of these teeth are thick and conical, convex on the labial surface, concave on the lingual; the fangs

are long, single, conical, compressed on the sides where they are marked by a shallow groove. In many mammals these teeth are developed into large projecting tusks,

The *Premolar* or *Bicuspid Teeth*, eight in number, two on each side of the mesial plane of each jaw, lie immediately behind the canines, and the upper bicuspid is somewhat larger than the lower. The crown is quadrilateral in form, and convex both on the inner and outer surfaces. It possesses two cusps, of which the outer or labial is larger and more projecting than the inner, palatal, or lingual cusp. The fangs of the upper bicuspid are single and laterally compressed; often bifid at the point into an outer and an inner segment; in the lower bicuspid the fangs are rounded, and taper to a single point.

The *Molar* or *Multicuspid Teeth*, twelve in number, are placed three on each side of the mesial plane of each jaw. They are the most posterior teeth, are the largest of the series, and as a rule decrease in size from the first to the last; the crowns of the lower molars are somewhat bigger than those of the upper molars. The last molar tooth does not erupt until the end of puberty, and is called *dens sapientiæ* or *Wisdom Tooth*. The crowns are broad, quadrilateral, and convex both on the inner and outer surfaces. The first and second upper molars have four cusps projecting from the angles of the grinding or masticating surface, and an oblique ridge often connects the large anterior internal cusp with the posterior external cusp; in the upper wisdom teeth, the two inner or palatal cusps are frequently conjoined. The first lower molar has five cusps, the fifth being interposed between the

two posterior cusps; in the second lower molar the fifth cusp is usually absent, or only rudimentary in size, but in the lower wisdom tooth it is often present. The fangs of the first and second upper molars are three in number, and divergent; two on the outer or buccal side, one on the inner or palatal side; in the upper wisdom the fangs are frequently partially conjoined, though trifid at the point. The fangs of the first and second lower molars are two in number, an anterior and a posterior, of which the anterior is the larger; they usually curve backwards in the jaw: in the lower wisdom the fangs are usually conjoined, but bifid at the point.

The crowns of all the teeth become more or less flattened by use, so that the incisors lose their sharp cutting edge, and the cusps of the premolars and molars are worn away.

The temporary or milk teeth are smaller than the permanent teeth. They are more constricted at the neck, where the crown joins the fang, especially in the milk molars, the fangs of which also diverge more widely than in the permanent set. The second temporary molar is bigger than the first. The crown of the first upper molar has three cusps, two buccal, one palatal: that of the second four cusps. The crown of the first lower molar has four cusps; that of the second five, three of which are buccal, two lingual. The temporary teeth lie more vertically in the jaws than the permanent.

The alveolus, or socket for the lodgment of the single fanged teeth, is a single socket; in the multi-fanged teeth, the socket is divided into two or three compartments, according to the number of fangs. The socket is lined by the

alveolo-dental periosteum, which is continuous at the mouth of the socket with the periosteal covering of the jaw and with the deeper fibrous tissue of the gum, where it embraces the neck of the tooth. At the bottom of the socket the alveolo-dental periosteum may be seen to have the character of a distinct layer of retiform connective tissue, on the one hand connected with the surface of the cement, on the other with the more fibrous periosteum lining the bony wall of the socket (fig. 207). Higher up the socket, the retiform character of the periosteal connective tissue gradually disappears, but nearer the mouth of the socket it reappears, and the stellate cells form a continuous network with similar cells in the deeper fibrous part of the gum. The alveolo-dental periosteum is vascular, its vessels being continuous with those of the gum, the pulp-vessels, and the bone. It receives nerves from those going to the pulp. The fang fits accurately in the socket, and through a hole at the tip of the fang the blood-vessels and nerves of the tooth pass into the pulp-cavity of the tooth.

Structure of the Teeth.

Each tooth is composed of the following hard structures.—dentine, enamel, and cement, or *crusta petrosa*; occasionally other substances, named *osteo-dentine* or *vaso-dentine*, are present. In a tooth which has been macerated, an empty space exists in its interior, called the pulp-cavity, which opens externally through the hole at the tip of the fang; but in a living tooth this cavity contains a soft, sensitive substance named the pulp.

The *Dentine* or *Ivory* makes up the greater part of each

tooth ; it is situated both in the crown, where it is covered by the enamel, and in the fang, where it is invested by the crusta petrosa ; whilst the pulp cavity in the centre of

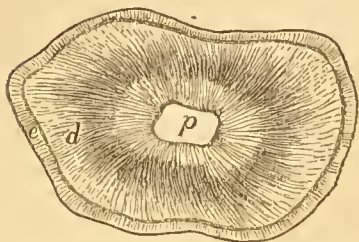


FIG. 205.—Transverse section through the crown of a tooth. *p*, pulp cavity ; *d*, dentine ; *e*, enamel. $\times 6$.

the tooth is a cavity in the dentine. The dentine is composed of an intimate admixture of earthy and animal matter in the proportion of 28 of the animal to 72 of the earthy. The animal matter is resolved on boiling into gelatine ;

the earthy matter consists mostly of salts of lime.

If thin slices through the dentine of a macerated tooth be examined microscopically, it will be seen to consist of a hard, dense, yellowish white, translucent *matrix*, penetrated by minute canals, called *dentine tubes*. The dentine tubes commence at the pulp cavity, on the wall of which they open with distinct orifices. They radiate in a sinuous manner from the pulp cavity through the thickness of the dentine, and terminate by dividing into several minute branches ; this division takes place in the crown of the tooth immediately under the enamel, and in the fang of the tooth immediately under the crusta petrosa. In their course the dentine tubes branch more than once in a dichotomous manner, and give off numbers of extremely minute collateral branches. The transverse diameter of the dentine tubes near the pulp cavity is $\frac{1}{4500}$ th inch, but that of their terminal branches is much more minute. When transverse sections are made through the tubes, they are seen to be bounded by a distinct circular line, which is

regarded as the sheath of the dentine tube ; for each tube is believed to have a definite wall, not formed of the matrix substance, though coalesced with it. By many observers the sheath is regarded as a calcified membranous tube.

If the dentine be examined in a fresh tooth, the tubes will be seen to be occupied by soft delicate, thread-like prolongations of the pulp. The passage of processes of the pulp into the dentine tubes was first seen by Owen in the examination of the tusk of an elephant ; but the soft contents of the dentine tubes have been made the subject of special investigation by J. Tomes in the human and other mammalian teeth, and have been named the *dentinal fibrils*. Sharpey has pointed out that the dentine possesses a laminated structure ; the lamellæ being arranged parallel to the wall of the pulp cavity. This laminated arrangement indicates the mode of formation of the dentine, as will be described on p. 762.

In sections through the dentine of dried teeth, it is not uncommon to find, near its periphery, irregular, black spaces containing air. These spaces freely communicate with each other. As the dentine which forms their boundary has not unfrequently the appearance of globular contours, they were named by Czermak the *interglobular spaces*. In a fresh tooth they are not empty, but are occupied by a soft part of the matrix, which is traversed in the usual manner by the dentine tubes. This matrix is apparently imperfectly calcified dentine, which shrinks up in a dried tooth, and occasions an air containing space. A layer of small irregular spaces situated in the peripheral part of the dentine in the fang, immediately under the

crusta petrosa, and sometimes named the *granular layer*, is apparently of the same nature as the interglobular spaces.

The *Enamel* is the brilliant white layer which forms a

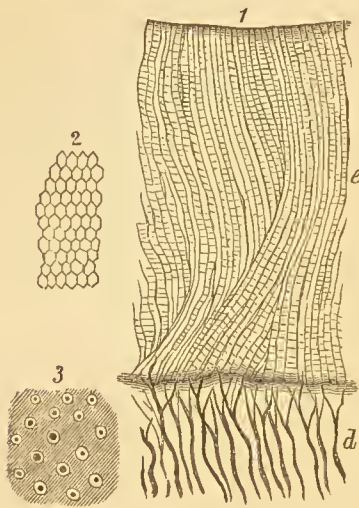


FIG. 206.—1, Vertical section through the Enamel and immediately subjacent Dentine. *e*, enamel rods; *d*, branched termination of dentine tubes. 2, transverse section through the enamel rods. 3, transverse section through dentine tubes and matrix. $\times 300$.

cap on the surface of the crown of a tooth. It is thickest on the cutting edge or grinding surface of the crown, and thins away towards the neck, where it disappears. It is not only the hardest part of a tooth, but the hardest tissue in the body, and consists of 96·5 per cent. of earthy and of 3·5 per cent. of animal matter. The earthy matter consists almost entirely of salts of lime. The great hardness of the enamel admirably adapts it as a covering for

the cutting edge, or grinding surfaces, of the crowns of the teeth.

When sections are made through the enamel perpendicular to the surface of the crown, it is seen to be composed of microscopic rods, named the *enamel fibres*, or *enamel prisms*. These rods are set side by side in close contact with each other; one end of each rod rests on the surface of the dentine, the other reaches the free surface of the crown. The rods do not all lie parallel to each other, for whilst some are straight, others are sinuous, and the latter seem

to decussate with each other. The rods are marked by faint transverse lines : they are solid structures in the fully formed enamel, and are polygonal in form. When cut across transversely, they are seen to be hexagonal or pentagonal, and about $\frac{1}{5000}$ th inch in diameter. Fissures are often seen extending into that surface of the enamel, which rests on the dentine ; and I agree with Tomes's statement, that dentine tubes may sometimes be seen to enter the deep surface of the enamel.

The free surface of the enamel of an unworn tooth is covered by a thin membrane, named the *cuticle of the enamel*, or *Nasmyth's membrane*. This membrane can be demonstrated by digesting an unworn tooth in a dilute mineral acid, when it separates as a thin flake from the free surface of the crown. It is a horny membrane, which resists the action of acids. Waldeyer states that when treated with a solution of nitrate of silver, it presents the appearance of figures like large epithelial cells. Its deep surface is pitted for the ends of the enamel rods. As the crown of the tooth comes into use, Nasmyth's membrane is worn off, and the enamel itself by prolonged use is thinned and worn down. In persons who live on hard food, that requires much mastication, it is not uncommon to find the grinding surface of the crowns of the molar teeth worn down quite flat, and the dentine exposed.

The *Cement*, *Crusta petrosa*, or *Tooth bone*, forms a thin covering for the surface of the fang of a tooth, and extends upwards to the neck. It is of a yellowish colour, and is usually thickest at the point of the fang ; though in the multifanged teeth it sometimes forms a thickish mass at the point of convergence of the fangs. It possesses the

structure of bone, and consists of a lamellated matrix with perforating fibres, lacunæ and canaliculi. The lacunæ are irregular in size and mode of arrangement, and vary also in the number of the canaliculi proceeding from them. Sometimes the canaliculi anastomose with the branched terminations of the dentine tubes. In the thin cement situated near the neck of the tooth the lacunæ are usually absent. If the jaw with its contained teeth be softened in acid, and sections be made so as to show the teeth *in situ*, there is no difficulty in recognising the cellular masses of nucleated protoplasm within the lacunæ, which resemble

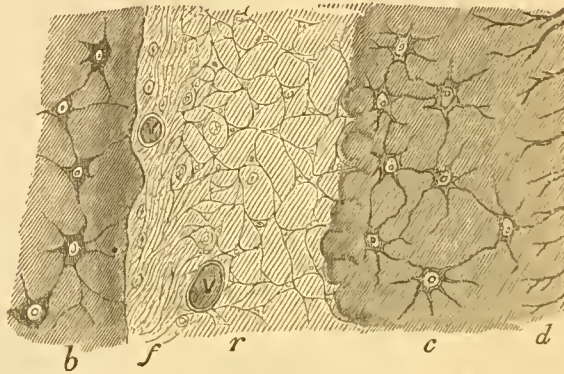


FIG. 207.—Section through the socket and fang of a Tooth. *b*, the bony wall of a socket, its lacunæ contain the bone corpuscles; *f*, the fibrous, and *r*, the reticulated portion of the alveolo-dental periosteum, in which transversely divided vessels, *v.v.*, may be seen; *c*, the cement, the lacunæ of which contain the bone corpuscles; *d*, the dentine. $\times 450$.

in appearance the corresponding structures in the adjacent bone. Haversian canals are only found in the cement, when it acquires unusual thickness. In old teeth the cement thickens at the tip of the fang, and often closes up the orifice into the pulp cavity; the passage of the nerves and vessels into the pulp is thus cut

off, and the nutrition of the tooth being at an end, it loosens in its socket and drops out. When the tooth is in its socket, the reticulated connective tissue of the alveolo-dental periosteum is closely attached to the outer surface of the cement.

Osteo-dentine and *Vaso-dentine* do not exist as normal structures in human teeth, though they occur in various animals. They may appear, however, as abnormalities in the human teeth, and are found on the inner wall of the pulp cavity. Osteo-dentine is a mixture of dentine structure, with lacunæ and canaliculi. If vascular canals, like the Haversian canals of bone, are formed in it, then the name vaso-dentine is applied.

The *Pulp* of the tooth is one of its most important constituents. It is a soft substance occupying the cavity in the dentine, or the pulp cavity, and is destroyed in a macerated and dried tooth. It consists of a very delicate gelatinous connective tissue, in which numerous cells are imbedded. Those which lie at the periphery of the pulp are in contact with the dentine wall, and form a layer, named by Kölliker the *membrana eboris*. As the cells of this layer play a part in the formation of the dentine, similar to that performed by the osteoblast cells in the formation of bone, Waldeyer has named them *odontoblasts*. The odontoblasts are elongated in form, and their protoplasm gives off several slender processes : some enter dentine tubes to form the soft dentinal fibres already described ; another passes towards the centre of the pulp, to become connected with more deeply-placed pulp cells, whilst others are given off laterally to join contiguous cells of the odontoblast layer. The pulp contains the

nerves and blood-vessels of the tooth, which pass into the pulp, through the foramen at the point of the fang. The vessels form a beautiful plexus of capillaries. The nerves are sensory branches of the fifth cranial nerve. They enter the pulp as medullated fibres, which divide into very fine non-medullated fibres, that form a network in the peripheral portions of the pulp. Boll detected delicate branches of this network passing outwards between the odontoblast cells, but no twigs were seen to enter the dentine tubes. The pulp of the tooth is the remains of the formative papilla, out of which the dentine or ivory has been produced. In adult teeth changes that lead to the production of osteo-dentine and vaso-dentine may take place in it. Through the dentinal fibres an organic connection is preserved between the dentine and the pulp, and the sensitiveness exhibited by the dentine in some states of a tooth is not necessarily due to the passage of nerves into it, but to its connection with the sensitive dentine pulp.

Development of the Teeth.

In studying the development of the teeth, not only has the mode of formation of the individual teeth to be examined, but the order of succession of the different teeth both in the temporary and permanent series.

The teeth are developed in the mucous membrane or gum, which covers the edges of the jaws of the young embryo, and their formation is due to a special differentiation in the arrangement and structure of portions of the epithelial and sub-epithelial tissues of that membrane. The enamel

is produced from the epithelium, and the dentine, pulp and cement from the sub-epithelial connective tissue.

The *development of the temporary teeth* will first be considered. If a vertical section be made through the mouth of a young human embryo about the 6th or 7th week, its cavity may be seen to be lined by a stratified epithelium, continuous with the layer of stratified epiblast forming the cuticle of the face. Along the edge of the gum, corresponding in position to that of the future jaws,



FIG. 208.—Vertical transverse section through the Mouth of a young Human embryo. *np*, naso-palatine region; *l*, tongue; *m*, mouth; *l, l, l, l*, lips; *d, d*, primitive dental grooves with epithelial contents in upper gum; *d', d'*, similar structures in lower jaws; *e, e*, cuticular epiblast; *h, h*, hair follicles; *e'*, epiblast prolonged into the mouth.

the epithelium is of some thickness, and an involution of the epithelium into the subjacent connective tissue has taken place. Owing to this involution a narrow furrow or groove in the connective tissue is produced, which constitutes the *primitive dental groove* of Goodsir. This groove is not, however, an empty furrow, but is occupied by the involuted epithelium. The sub-epithelial connective tissue is soft and gelatinous, and abounds in corpuscles, which are especially abundant in the connective tissue at the

bottom of the groove, where the *dental papillæ* are produced. These papillæ form, at the bottom of the groove by an increased development and growth of the corpuscles of the subjacent connective tissue. The base of each papilla is continuous with the subjacent connective tissue, and the

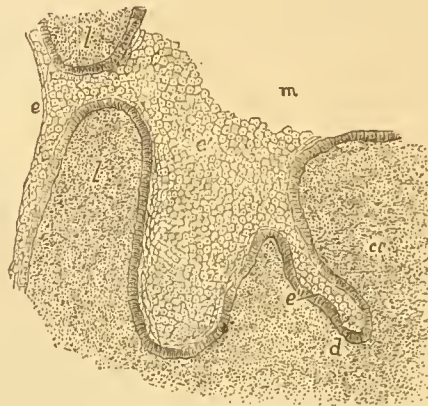


FIG. 209.—A more highly magnified view of a section through the same jaw as fig. 208; *ct*, sub-epithelial connective tissue of the gum; *d*, primitive dental groove; *e''*, its epithelium; *e'*, epithelium lining *m*, the cavity of the mouth; *l*, *l'*, lips; *e*, the epiblast cuticle. The deepest layer of the epithelium consists of columnar cells.

apex projects into the deeper part of the involuted epithelium. As a papilla increases in breadth and length, the groove widens and deepens, and the involuted epithelium increasing in quantity, expands over the apex and sides of the papilla, so as to form a hood-like covering or cap for it. The cap of epithelium constitutes the *enamel organ*, whilst the papilla is the *formative pulp* for the dentine and permanent pulp. Whilst these changes are taking place in the epithelium and the connective tissue at the bottom of the groove, no commensurate widening occurs at its upper part, which remains for a time relatively narrow, but retains within it

a narrow string of epithelial cells, continuous on the one hand with the epithelial lining of the mouth, and on the other with the enamel organ. This epithelial string forms the *neck of the enamel organ*. After a time, however, the

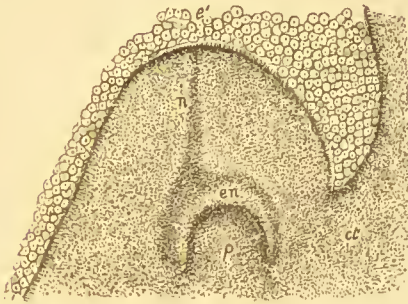


FIG. 210.—Vertical section through the gum to show the formation of the Dental Papilla. *e'* the epithelium covering the gum; *n*, the neck of *en*, the enamel organ; *p*, the dental papilla; *ct*, sub-epithelial connective tissue. Magnified.

growth of the connective tissue, forming the lips of the primitive groove, causes the neck of the enamel organ to atrophy, so that all communication between the enamel organ and the superficial epithelium

is cut off; the connective tissue on the opposite lips of the groove becomes continuous, and the embryo tooth, being now completely enclosed in a cavity or sac, formed by the gelatinous connective tissue of the gum, has entered on what Goodsir termed its *saccular* stage of development.

When enclosed in its sac the embryo tooth, though perfectly soft, acquires a shape, which enables one to recognize to what group of teeth it belongs. After a time it begins to harden and to exhibit the characteristic tooth structure.

The dental papilla is more vascular than the surrounding connective tissue, from the blood-vessels of which its vessels are derived. The papilla abounds in cells which are, in the first instance, rounded and ovoid in shape. Changes then take place in the cells situated at its periphery, which become elongated and branched, and form layers of cells, which Waldeyer has appropriately named *odonto-*

blasts. Calcification of the protoplasm of these odontoblasts then occurs, and the peripheral layer of the dentine



FIG. 211.—Sacculated stage of development of two molar teeth in the Cat. *ct, ct*, connective tissue forming the sacs for the teeth; *p, p*, dental papillæ; the opaque bands *d, d*, mark the commencement of calcification of the dentine; *e, e*, internal enamel epithelium; the outer enamel epithelium was not recognisable. *b, b*, the bony walls of the alveoli are beginning to form. Magnified.

is produced. In contact with the inner surface of the thin film of dentine, a second layer of odontoblast cells is then arranged, which in its turn calcifies, and as the process goes on in successive layers of odontoblasts, the entire thickness of the matrix of the dentine and the dentinal sheaths are produced. It is owing to this circumstance that the dentine may exhibit the laminated arrangement referred to on p. 753. But the process of calcification does not apparently take place throughout the whole thickness of the protoplasm of the odontoblasts, for, as Waldeyer pointed out, the axial part of the cells remains undifferentiated, as the soft dentinal fibrils of the dentine tubes. As these changes are going on in the peripheral layers of the odontoblasts, the central part of the papilla

increases in quantity, apparently by a proliferation of its cells; nerve fibres are developed in it; it does not undergo calcification, and persists as the pulp of the tooth. The papilla of the tooth has essentially, therefore, the same

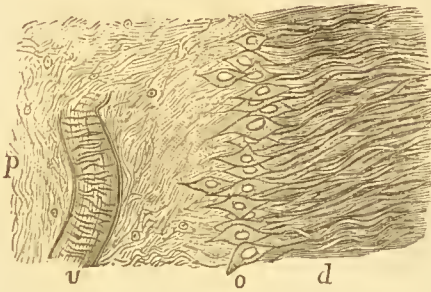


FIG. 212.—Section through the dentine and pulp cavity of a young tooth. *p*, the pulp, with *v*, one of its vessels, and *o*, layers of odonto-blast cells giving off processes into *d*, the dentine. $\times 450$.

relation to the formation of dentine that the cellulo-vascular contents of the medullary spaces, in intra-cartilaginous ossification, have to the formation of bone. In both instances the hard matrix is due to a special differentiation of the protoplasm of the formative cells; the dentinal fibrils are the equivalent structures to the soft contents of the lacunæ and canaliculi, and the persistent pulp is equivalent to the cellulo-vascular contents of the Haversian canals.

Prior to the embryo tooth becoming sacculated, changes had taken place in the enamel organ. Those cells of the enamel organ, which lie next the dental papilla, are continuous through the neck of the enamel organ, with the deepest layer of cells of the oral epithelium, which cells are elongated columns set perpendicularly to the surface on which they rest. Similarly the cells of the deepest

layer of the enamel organ are columns set perpendicularly to the surface of the dental papilla. They undergo a greater elongation, and form six-sided prismatic cells, which Kölliker has named the *internal* or *enamel epithelium*. The cells of the most superficial layer of the enamel organ lie in contact with the vascular connective tissue, which

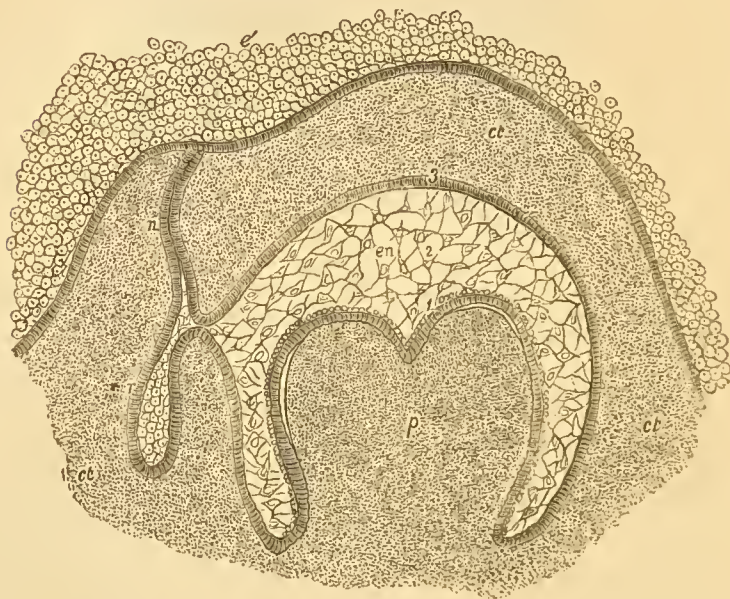


FIG. 213.—Vertical section through gum of Sheep in the region of the molar teeth. *p*, the papilla of a milk molar; 1, the inner, 2, the middle, and 3, the outer layers of the enamel organ; *n*, the neck of the enamel organ; *e'*, the superficial epithelium; *ct, ct, ct*, the sub-epithelial connective tissue which subsequently forms the sac of the tooth; *r*, the cavity of resere occupied by epithelium, in connection with which the permanent successional tooth is formed. $\times 300$.

encloses the embryo tooth. They form the *external epithelium* of the enamel organ, and slender papillary prolongations of the connective tissue frequently project into this epithelial layer. The cells of the enamel organ, situated between its external and its internal epithelium, become

stellate, and form with each other an anastomosing network of cells like those sometimes seen in the gelatinous connective tissue.

After the tooth has become sacculated, and coincident with the transformation of the odonto-blast cells of the dental papilla into dentine, calcification begins in the elongated prismatic cells of the internal or enamel epithelium; their protoplasm becomes calcified, and they become the rods or prisms of the enamel. As the hardening takes place from the periphery to the centre of each cell, the axial portion may, as Tomes pointed out, remain soft for some time in the axis of the enamel rod. With the increase in length and with the calcification of the cells of the enamel epithelium, the stellate gelatinous cells disappear, and the outer ends of the enamel rods come in contact with the cells of the external enamel epithelium. By some observers the external epithelium is supposed to disappear without undergoing any special differentiation, but by others it is believed to undergo conversion into Nasmyth's membrane.

In this manner the crown of a tooth is formed, and it is lodged in a membranous sac formed by the differentiation into a fibro-vascular membrane of the surrounding connective tissue. Whilst within its sac the crown of the tooth possesses the characteristic form of the group of teeth to which it belongs. After the calcification of the enamel rods is completed, it can undergo no further change either in shape, or in increase of size.

Whilst the crown of the tooth is being formed, ossification of the jaws has been going on, and the tooth, with its membranous sac, has become lodged in an alveolus or

socket in the jaw, which alveolus is closed in by the gum. In order that the crown of the tooth may come into use as a masticatory organ, it has to be elevated to the level of the gum, which is absorbed by the pressure, and the crown then erupts into the cavity of the mouth. The process of eruption is due to the development of the fang, which, as it grows in length, elevates the crown of the tooth and forces it outward. The dentine of the fang is developed from the odonto-blast cells of the pulp in a manner similar to that already described for the development of the dentine of the crown. The cement or crusta petrosa is developed from the connective tissue lining the alveolus, which forms the alveolo-dental periosteum. It is therefore an ossification in membrane.

As the temporary or milk teeth precede the permanent

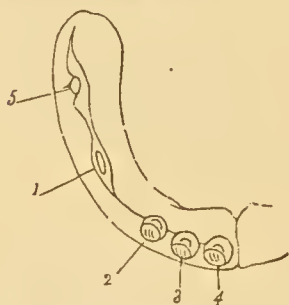


FIG. 214.—One-half the lower jaw of a fœtus about the 11th or 12th week, showing the dental papillæ in the order of their appearance. 1, the first milk molar; 2, the canine; 3 and 4, the two incisors; 5, the second milk molar.—From Goodsir.

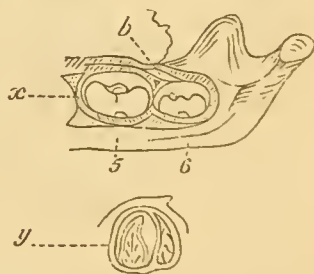


FIG. 215.—Posterior part of the lower jaw of a child at birth. 5, the crown and sac of the posterior milk molar; 6, the crown and sac of the first permanent molar; *b*, the cavity in connection with which the papilla of the second permanent molar ultimately forms. *y*, shows a temporary and permanent incisor from the same fœtus.—From Goodsir.

teeth, their papillæ are naturally the first to form. The

series of milk-papillæ are not, however, simultaneously produced. From the observations of Goodsir, it has been shown that the milk-papilla of the anterior molar in the upper jaw appears about the seventh week, then the canine papilla, the two incisor papillæ, and the posterior molar papilla are successively formed, the last making its appearance about the end of the tenth week. The dental papillæ in the upper jaw immediately precede the papillæ of the corresponding teeth in the lower jaw.

The eruption of the milk teeth into the mouth does not begin to take place until the latter half of the first year of extra-uterine life, and is not completed until between the second and third year. Though variations occur in the date of eruption of each tooth in different children, it may be stated that the incisors usually appear from the seventh to the ninth month; the anterior molars from the twelfth to the sixteenth month; the canines during the seventeenth or eighteenth month; the posterior milk molars from two to two and a half years. The milk teeth begin to be shed about the sixth year by the dropping out of the incisors. The last to be shed are the canines, which do not fall out until the tenth or eleventh year. The shedding of the milk teeth is preceded by the absorption of the fangs. This is effected, as was satisfactorily shown by J. Tomes, by the agency of a group of cells situated at the bottom of the sockets. As these cells occasion absorption of the tooth tissue, similar to that occurring in the bone tissue from the action of the large, many nucleated osteo-klast cells (p. 172), they may appropriately be called *odonto-klasts*.

The *development of the permanent teeth* will now be considered. In the description of the arrangement of the

teeth it has been pointed out that the number of teeth in the permanent set exceeds that of the temporary set. The permanent incisors and canines come into the place of the temporary incisors and canines; the permanent bicuspid succeeds the temporary molars, but the permanent molars have no milk predecessors, and are superadded at the back of the dental series.

The development of the *successional permanent teeth*, which are the ten anterior teeth in each jaw, will first be examined. Prior to the period when the lips of the primitive dental groove meet, to produce the saccular stage of dentition of the several temporary teeth, an indentation, or furrow, takes place in the connective tissue adjoining the string of epithelial cells, forming the neck of the enamel organ. This furrow constitutes what Goodsir termed the *cavity of reserve*, and it is filled up by epithelial cells continuous with the epithelium of the neck of the enamel organ. As a cavity of reserve is formed immediately behind, *i.e.*, on the lingual side of, each milk tooth, they are ten in number in each jaw, and, except that for the anterior molar, are formed successively from before backwards.

The cavities of reserve are concerned in the production of the permanent successional teeth, and each temporary tooth is replaced by the permanent tooth formed in connection with the cavity of reserve situated immediately behind it (fig. 213). The cavities of reserve become elongated, and widened, and pass above the temporary teeth in the upper jaw, and below those in the lower jaw. At the bottom of each a dental papilla forms, the apex of which indentates and becomes covered by the epithelium

contained in the cavity, which forms a cap for the papilla, and constitutes the enamel organ for the permanent tooth. The cavity becomes completely closed by the growth of the surrounding connective tissue, and the embryo permanent tooth becomes sacculated. The process of calcification then goes on, in both the enamel organ and dental papilla, in a manner similar to that already described in the temporary teeth. The permanent teeth then become lodged in sockets in the jaw distinct from those of the temporary teeth. The sac of each permanent tooth remains connected with the fibrous tissue of the gum by a slender fibrous band, or *gubernaculum*, which passes through a hole in the jaw immediately behind the corresponding milk tooth. Before the successional permanent tooth erupts, not only should the temporary tooth be shed, but the bony partition between their respective sockets must be absorbed.

The *superadded permanent teeth*, or permanent molars, three in number on each side, lie behind the successional

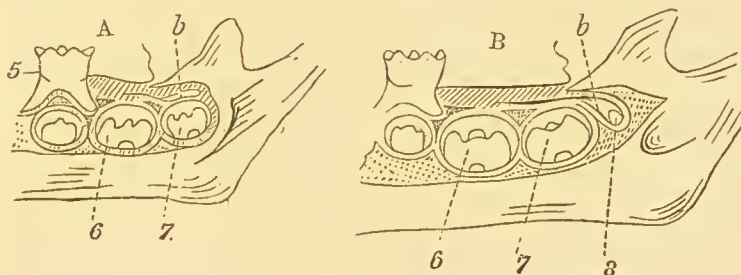


FIG. 216.—A, the lower jaw of a child between four and five years old. 5, the last milk molar, with the successional bicuspid tooth in the cavity of reserve immediately below it; 6 and 7, the first and second permanent molars in their sacs; b, the cavity in connection with which the wisdom tooth is formed. B, the lower jaw of a child about six years old; 6 and 7, the first and second permanent molars; 8, the papilla of the wisdom tooth developed in connection with its cavity b.—From Goodsir.

teeth. Their mode of origin is similar to that of the

temporary teeth. The primitive groove, occupied by an involution of the epithelial covering of the gum, is prolonged backwards. Three dental papillæ successively appear at the bottom of this groove, and the epithelium covering each papilla forms its enamel organ. Legros and Magitot, however, state that the 2nd permanent molar arises in connection with a diverticulum (cavity of reserve) proceeding from the epithelial string of the enamel organ of the 1st permanent molar, and that the wisdom tooth is formed in connection with a similar diverticulum from the 2nd permanent molar. The embryo tooth becomes sacculated, and goes through the process of calcification similar to what has been described in the other teeth.

The germ of the 1st permanent molar appears about the sixteenth week of embryo-life : that of the 2nd permanent molar not until about the seventh month after birth, whilst that of the wisdom tooth is not formed until about the sixth year. The crown of the first molar is the first of the permanent teeth to erupt into the mouth, which it usually does in the sixth year. The incisors appear when the child is 7 or 8 ; the bicuspidis when it is 9 or 10 ; the canines about 12 ; the second molars about 13 ; and the wisdom teeth from 17 to 25.

In his dentition man is diphyodont as regards his incisors, canine, and premolar teeth ; but monophyodont in the molar series.

From the description of the development of the teeth, it will have been seen that a tooth is an organ composed of three hard tissues, enamel, dentine and cement, and of the soft vascular and nervous pulp. These tissues are not developed from one layer only of the blastoderm. The

enamel is of epiblast origin, whilst the dentine, cement, and pulp are derived from the mesoblast. A tooth in its fundamental development, as was long ago pointed out by Goodsir, must be referred to the same class of organs as the hairs and feathers. The enamel of the tooth, like the hair, is produced by a differentiation of the involuted epithelium of the epiblast, whilst the dentine and pulp resemble the papilla of the hair, in proceeding from the mesoblast. The tooth-sac, like the hair follicle, is also of mesoblast origin. Whether the cement, as Robin and Magitot have described, be developed by means of a special *cement organ*, in the interior of the tooth-sac, or is formed, as has been stated in this description, by the alveolo-dental periosteum, it is derived from the mesoblast. As to the origin of Nasmyth's membrane, there is a difference of opinion; some regard it as a special cornification of the external cells of the enamel organ, in which case it would be from the epiblast; whilst others consider it to be continuous with, though structurally different from, the cement—homologous, therefore, with the layer of cement, which in the horse, ruminants, and some other mammals, covers the surface of the crowns of the teeth. As to the *membrana preformativa*, which some writers have described between the enamel organ and the dentine papilla, and others between the enamel and the enamel organ, I have not been able to see it in any of the developing teeth which I have examined: I therefore agree with C. S. Tomes in believing it not to be present.

The tissues of a tooth have not all the same importance in the structure of a tooth. The dentine is apparently always present, but the enamel, or the enamel and cement,

may be absent in the teeth of some animals. For example, the tusks of the elephant and narwhal, and the teeth of the Edentata, are without enamel, and, in the Rodentia, enamel is present on only the anterior surface of the incisors. But though the enamel is not developed, or forms only an imperfect covering for the crowns of these teeth, yet an enamel organ is formed in the embryo jaws. In 1872 I described a structure homologous with the enamel organ in relation with each of the dental papillæ in the lower jaw of a foetal narwhal; but this organ did not exhibit a differentiation into the three epithelial layers, such as occurs in those teeth in which enamel is developed. Since then C. S. Tomes has seen an enamel organ in the embryo armadillo, and has also pointed out that, in teeth generally, enamel organs exist, quite irrespective of whether enamel subsequently does or does not form.

But further, the involution of the oral epithelium, and the coincident formation of a primitive groove, take place not only where the teeth subsequently arise, but along the whole curvature of the future jaws; whilst the production of dental papillæ is restricted to the spots where the teeth are formed. Hence I am disposed to consider the inflection of the oral epithelium as not so essential to the development of a tooth, as the formation of a papilla. The inflected epithelium marks only a preliminary stage, and it may or may not be transformed into tooth structure. But that which is essential to the formation of a tooth is the production of the papilla which appears at the bottom of the primitive groove.

DEVELOPMENT OF THE DIGESTIVE AND RESPIRATORY SYSTEMS.

The Digestive and Respiratory Systems are for the most part developed from the mesoblast and hypoblast layers of the blastoderm, the epiblast having but a limited share in their formation.

When the differentiation of the blastoderm into three layers has taken place, its deepest or hypoblast layer lies in contact with the yolk, and is in the course of time prolonged over it to form the epithelial layer of the wall of the umbilical vesicle. As the axial part of the body of the embryo rises up from the surface of the yolk (through the occurrence of those changes in the epiblast and mesoblast which lead to the formation of the nervous axis, the chorda dorsalis, and the protovertebræ (p. 211), a fold takes place at both the cephalic and caudal ends of the embryo. At the same time the hypoblast, both anteriorly and posteriorly, becomes folded so as to form the anterior and posterior ends of a tube, whilst the intermediate part of the hypoblast continues to invest the yolk as the wall of the *umbilical vesicle*. The hypoblast tube, owing to the folding at its anterior and posterior ends, forms, in front and behind, a *cul-de-sac*; but its intermediate part relatively has the form of a wide furrow, and communicates freely with the yolk sac. Subsequently, as the hypoblast assumes the tubular shape, in the intermediate part likewise the communication becomes constricted, and forms the *omphalo-mesenteric duct*. The tube in its whole length is the *Primitive Alimentary Canal*.

At the same time important changes are going on in the mesoblast on each side of the protovertebræ. It splits into two layers, one of which, named the *somato-pleure layer*, adheres to the epiblast, and forms with it the ventral wall of the body of the young embryo; for as it increases in size it grows towards the ventral surface of the body, and encloses the future thoracic and abdominal cavities. At the umbilicus, however, an opening remains in the mesial ventral line, which permits the structures constituting the umbilical cord, to pass out to the placenta. The other layer of the mesoblast, named the *splanchno-pleure layer*, adheres to the hypoblast, and along with it forms the primitive alimentary canal, and the several viscera which are developed as diverticular offshoots from that canal. Owing to the extension of the somato-pleure, with its cuticular covering of epiblast, to the ventral mesial line of

the embryo, the splanchno-pleure and hypoblast are included within the thoraco-abdominal chamber. The splitting of the mesoblast into two layers occasions a cavity between the somato-pleure and splanchno-pleure, which cavity forms the *pleuro-peritoneal cavity*.

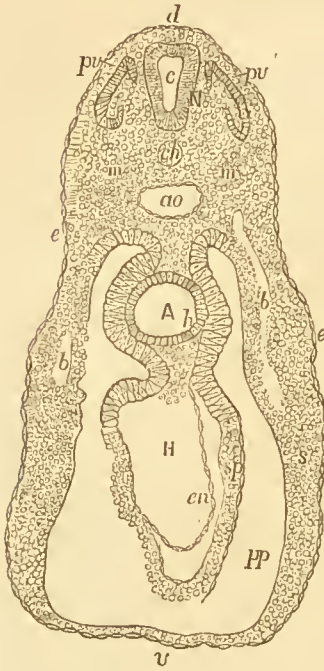


FIG. 217.—Transverse section through the body of an embryo Chick about the 3rd day. *d*, dorsal, and *v*, ventral surface of embryo; *N*, neural axis; *c*, central canal; *ch*, chorda dorsalis; *pv*, protovertebrae; *m*, *m*, mesoblast; *e*, *e*, epiblast; *ao*, aorta; *A*, primitive alimentary canal; *h*, hypoblast; *H*, heart; *en*, endocardium; *sp*, splanchno-pleure; *s*, somato-pleure; *pp*, pleuro-peritoneal cavity; *b*, *b*, divided vessels in the wall of the body.—Modified from Schenk.

The *Primitive Alimentary Canal* is a straight, or almost straight tube, and lies in relation to the ventral surface of the chorda dorsalis, and the bodies of the vertebrae which are developed around the chorda. From its anterior closed end, or the *fore-gut*, are developed the pharynx, cesophagus, stomach, and duodenum. From its posterior closed end, or the *hind gut*, are developed the rectum, and sigmoid flexure of the colon. From its intermediate part, or the *middle gut*, are developed the jejunum and ileum, the cecum, and the greater part of the colon.

In the differentiation of the walls of the primitive tube, which leads to the formation of these different divisions of the alimentary canal, the cells of the hypoblast are transformed into the epithelium situated on the surface of its mucous membrane, whilst the

muscular and connective tissues, the vascular and nervous structures in the wall of the several divisions of the canal, are differentiated from the cells of the mesoblast.

The *primitive pharynx* is the most anterior part of the primitive alimentary canal, and is enclosed by the visceral and vascular arches in the head of the embryo. As the pharynx lies in the embryo head, the splitting of the mesoblast into the two definite layers of somato-pleure and splanchno pleure, is not seen in con-

nection with it, but that part of the mesoblast, which differentiates into the muscular coat, and into the several layers of connective tissue entering into the formation of the pharyngeal wall, is continuous with the splanchnopleuric layer belonging to the other divisions of the alimentary canal. Its anterior end is closed, and has at first no communication with the mouth, which is not developed from the primitive alimentary canal.

The *mouth* is formed on the facial aspect of the early embryo, by an involution of the epiblast and of the immediately subjacent mesoblast, so as to form a pit, or depression, situated between the superior maxillary plates and the mandibular or first pair of visceral arches. This pit deepens, and widens into the buccal cavity. At first it freely communicates with the embryo nasal chamber, but is subsequently cut off from it by the formation of the hard palate, though the anterior palatine foramina, which in many animals remain patent, keep up the original communication between the oral and nasal chambers. The lining epithelium of the mouth is therefore of epiblast origin, and is continuous with the epiblast cuticle at the margins of the lips (fig. 208). An aperture of communication is formed in the course of time between the mouth and pharynx, so that they become continuous with each other, the communication being established at the fauces or pharyngo-oral aperture.

The *œsophagus* is the part of the primitive canal which immediately succeeds the primitive pharynx, and when the formation of the visceral chambers is completed, it lies successively in the neck, thorax, and abdomen.

The *stomach* is at first a straight, and but little dilated part of the canal, lying vertically in the visceral chamber, and connected to the ventral surface of the spinal column by a fold of the mesoblast, named the *mesogastrium*. As the stomach dilates and assumes its curvatures, it turns over on its right side, so that the original left surface becomes anterior, and the right surface posterior. This change in position explains why the left vagus supplies the anterior wall of the stomach, and the right vagus the posterior wall. The mesogastrium becomes the great omentum.

The *duodenum* is the last part of the alimentary canal developed from the fore-gut. It also loses its straight direction, and forms a horse-shoe curve.

The *jejunum* and *ileum* are at first a simple loop of the primitive middle gut, which is connected to the ventral surface of

the spine by a fold of the mesoblast, named the *mesentery*. This loop at first protrudes out of the abdominal chamber through the umbilical opening, along with the allantois and the vessels of the umbilical cord, but it is soon withdrawn into the abdomen. The portion of the loop which becomes the ileum was originally continuous with the umbilical vesicle through the *omphalo-mesenteric*, or *vitello-intestinal duct*; but this duct atrophies, and in the course of time disappears. As the jejunum and ileum increase in length, they become more and more convoluted, and produce the coils of the small intestine.

A blind sac appears in the course of the middle gut beyond the place of union with the omphalo-mesenteric duct. This sac is the rudimentary *cæcum*, or commencement of the large intestine. The remaining part of the middle gut forms a portion of the colon. The cæcum undergoes a great expansion, except at its lower part, which remains of small calibre and forms the *appendix vermiformis*. The colon also expands into the large intestine, and is continuous with the rectum, formed by a growth and dilatation of the primitive hind gut. The cæcum and colon lie in their early stage to the left of the mesial plane, but, as they increase in length, they pass into the right hypochondrium, and then descend through the right lumbar region into the right iliac fossa. In some cases the descent of the cæcum does not take place, and it then remains in the adult in the right lumbar region, or even in the right hypochondrium, where I have occasionally seen it. In other cases it descends lower down into the pelvis.

The *rectum* and apparently the *sigmoid flexure of the colon* are produced by growth and expansion of the primitive hind gut. The posterior end of the hind gut is at first a *cul-de-sac*, but the mesoblast and epiblast wall of the body, opposite the end of the gut, becomes involuted and absorbed, and the gut then opens into a fossa called the *eloaca*, common to it and to the external orifices of the genital tube and the urethra. In the course of time the intestinal orifice becomes completely separated from the genito-urinary, by the growth of integument, and the *anal orifice* is formed. The imperforate anus, sometimes found in new-born children, is due to the communication between the blind end of the rectum and the surface never having been established.

From the terminal part of the primitive hind gut a diverticulum, called the *allantois*, sprouts out, the several stages of the development, and atrophy of which will be described in connection with the development of the genito-urinary apparatus.

In the wall of the alimentary canal are developed numbers of racemose glands, of tubular gastric glands, and of tubular Lieberkühnian glands. The epithelial cells lining the ducts of the *mucous and salivary glands* opening into the mouth are involutions of its lining epiblast epithelium, and the secreting cells within the gland vesicles are probably derived from the same layer, whilst the connective tissue, vessels, and nerves of these glands are developed from the mesoblast.

The epithelium of all the *tubular glands* situated in the wall of the stomach and intestine is of hypoblast origin. The epithelial lining of the ducts of *Brunner's glands*, and of the *racemose glands* in the wall of the pharynx and œsophagus, is derived from the hypoblast, but there is a question how far the secreting cells within the gland vesicles are of hypoblast or of mesoblast origin. The *lymphoid follicles* and *lymphatic glands* are developed from the mesoblast.

The *Pancreas* is developed along with the spleen from a clump of mesoblast situated in connection with the wall of the duodenum. A diverticulum of the hypoblast lining of the duodenum grows into it, which gives rise to the epithelial lining of the pancreatic duct; but as to the cellular contents of its gland vesicles, as well as those of Brunner's glands, it is not yet determined whether they are derived from mesoblast or hypoblast.

The *Liver* arises from one or two masses of mesoblast situated in connection with the wall of the duodenum. A diverticulum from the hypoblast lining of the duodenum is prolonged into it, which branches and forms the epithelial lining of the bile ducts and gall bladder. Columns of cells then arise in the embryonic organs, which come into relation with the branched divisions of the diverticulum from the hypoblast. These columns form the secreting cells of the liver, but there is a difference of opinion as to whether they are produced from the mesoblast cells, or from the hypoblast diverticula. The vessels, nerves, and connective tissue, both of the liver and pancreas, are produced by differentiation of their mesoblast cells.

The Organs of Respiration are developed in connection with the wall of the primitive alimentary canal.

The *Lungs* arise as two bud-like projections in the wall of the primitive fore gut, in the region of the primordial heart and liver. These buds are hollow, and consist of collections of mesoblast cells, into which a diverticulum of the hypoblast lining of the fore gut is prolonged. Growth and thickening of the anterior or ventral wall

of the fore gut takes place, which differentiates into the *larynx* and *trachea*. From the lower end of the trachea the two *bronchi* proceed, which become continuous with the hollow space in the embryo lungs. The characteristic lung substance is produced by repeated divisions and subdivisions of the bronchial tube, and by growth within the lung, which produces the lobular and vesicular structure of the air cells. The hypoblast cells form the epithelial lining of the windpipe and air cells; whilst the mesoblast cells differentiate into the connective tissue of the lungs, its vessels and nerves, and the cartilaginous, muscular and fibrous structures in the walls of the bronchi and air cells. In its general mode of development the lung closely corresponds with that of a racemose gland; but the alveoli or air vesicles of the lung are not occupied by secreting cells as are the vesicles of the racemose glands.

The trachea is formed in relation to the ventral aspect of the oesophageal part of the fore gut, and the larynx to the pharyngeal part; the larynx opens into the pharynx. At the ninth week of intra-uterine life the cartilages of the larynx are formed, and the cartilage of the epiglottis, up to about the sixth month, has the structure of hyaline and not of yellow fibro-cartilage.

The *pleuro-peritoneal cavity*, situated between the somatopleure and splanchnopleure layers of the mesoblast, becomes lined by an endothelium, produced by a differentiation of the mesoblast cells situated next to the free surface of each layer. As the splanchnopleure layer differentiates into the outer coats of the several viscera which have just been described, the cells covering its free surface form the endothelium of the visceral layer of the serous membrane enveloping the viscera; whilst the cellular covering of the somatopleure layer forms the endothelium of the free surface of the parietal part of the serous membrane. The pleuro-peritoneal cavity on each side of the body of the embryo is one chamber, but, by the development of the diaphragm, the pleura and lung become shut off from the peritoneum and abdominal viscera. Occasionally, the development of the diaphragm is incomplete, and a communication remains between the pleural and peritoneal chambers. Through the gap the abdominal viscera may project into the pleural sac and occasion a diaphragmatic hernia. The heart was originally in relation to the pleuro-peritoneal space, but becomes shut off from it by the development of the fibro-serous wall of the pericardium.

CHAPTER XI.

URINARY SYSTEM.

THE Urinary Organs are for the purpose of separating from the blood, and conveying out of the body, certain materials, such as urea and uric acid, formed by the oxidation within the body of its nitrogenous constituents. These materials are dissolved, along with various salts, in a large proportional quantity of water, and the solution constitutes the Urine. The secretion is formed in a pair of glands, the Kidneys. The excretory apparatus for conveying it from the kidneys to the surface of the body, consists of a duct from each kidney, the Ureter; of a reservoir, the Urinary Bladder, into which these ducts open; and of a single duct, the Urethra, leading from the bladder and opening on the surface of the body.

THE KIDNEYS.

The kidneys are two in number, and are placed in relation to the posterior wall of the abdominal cavity, one on each side of the mesial plane. They are situated in the right and left lumbar regions, and reach, from about

the level of the upper border of the 12th dorsal vertebra, downwards to the level of the 3rd lumbar. Luschka

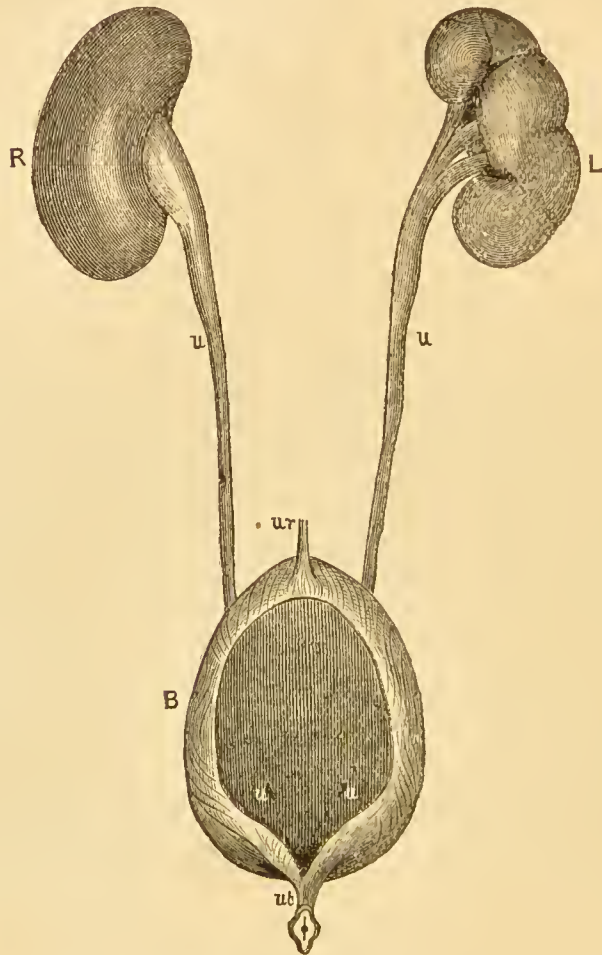


FIG. 218.—The Urinary Organs in the female. R, the right, and L, the left kidney; the left kidney is drawn with fissures on its surface, such as are sometimes seen marking its separation into lobules; U, U, the ureters; B, the bladder, in which are *u, u*, the openings of the ureters; *ut*, the urethra; *ur*, the urachus.

states that they may reach as high as the level of the middle of the 11th dorsal vertebra. As a rule, the left

kidney is a little higher than the right. The hilus of the kidney is opposite the 1st lumbar vertebra. The kidneys lie behind the peritoneum, and are surrounded by a mass of fat and loose areolar tissue.

Each kidney is about 4 inches long, 2 to 3 inches wide, and from 1 to 1½ inch in thickness. The average weight is between 4 and 5 oz.

The shape of the kidney is characteristic. It possesses two surfaces, two borders, and two extremities. The *anterior surface* is convex, and looks forwards and outwards; on the right side it is in relation to the duodenum and ascending colon, on the left side to the descending colon. The *posterior surface* is flattened, and rests on the crus of the diaphragm, and on the fascia covering the quadratus lumborum and psoas muscles: on a plane still more posterior to the upper part of this surface, are portions of the 11th and 12th ribs. The *outer border* is convex, and directed towards the postero-lateral wall of the abdomen. The *inner border* is concave, and directed forwards towards the spine: the deep fissure in this border is called the *hilus*, and allows of the passage of the vessels, nerves, and ureter into or out of the kidney. The *upper extremity* is thicker and more rounded than the lower, and has the supra-renal capsule in relation with it. The upper end of the right kidney, and the immediately adjacent part of the anterior surface, are in relation to the liver; the corresponding parts of the left kidney are in relation to the spleen. The *lower extremity* is smaller and thinner than the upper, and does not reach so low as the level of the crest of the ileum.

In rare cases one kidney has been known to be con-

genitally absent. Occasionally the upper ends of the two kidneys have been seen to be united together by an intermediate portion of kidney substance, situated in front of the abdominal aorta, when the conjoined organs formed a horseshoe-shaped kidney.

Structure of the Kidney.

The kidney, though situated in the abdomen, does not possess a serous coat. In rare instances, however, the peritoneum has been seen to invest it more or less completely, and in these cases the kidney was not a fixed, but a movable organ, known as a *floating kidney*.

The *proper coat* of the kidney is a fibrous membrane completely investing the organ. It can be readily stripped off the surface, and in doing so very delicate processes of connective tissue may be seen passing from its deep surface into the substance of the kidney. It is also continuous at the hilus with the sheaths of the various structures, which enter the gland. The inner layer of the proper coat contains a wide-meshed network of non-striped muscular fibres. When the fibrous coat is stripped off, the surface of the kidney is seen to be quite smooth, and of a brownish-red colour. In infants and children it is not unfrequent to find fissures extending for some distance into the substance of the kidney, a condition which indicates the lobular construction of the gland. In some mammals, as the ox, the bear, the cetacea, the lobules can be readily separated from each other, and the organ is divided into numerous independent *renules*; but in the human

kidney, that of the sheep, and of mammals generally, the lobules become fused together into a single organ.

To obtain a knowledge of the structure of the gland, it will be necessary to make longitudinal sections through the organ from the convex border to the hilus. When this is done, the ureter will be seen to enter the kidney at the hilus, and to dilate into a wide *pelvis*, which divides, either directly or indirectly, into several short, truncated

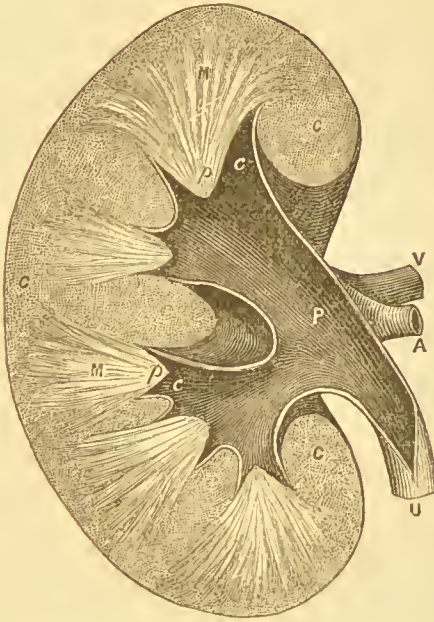


FIG. 219.—A longitudinal section through the kidney. C, C, C, the cortical substance; M, M, the medullary pyramids; p, p, the papillæ; c, c, the calyces of the ureter; P, the pelvis; U, ureter; A, renal artery; V, renal vein.

branches, the *calices*, or *infundibula*. The substance of the kidney itself consists obviously of two parts, an external highly vascular part forming the surface of the kidney, and named the *cortical portion*; and an internal or central part, next the calices and pelvis, named the

medullary portion. As prolongations of the cortex, named the *columns of Bertin*, dip into the medullary part, they divide the latter into from ten to eighteen distinct masses, each possessing a pyramidal form; they are named the *medullary pyramids*, or *pyramids of Malpighi*. The base and sides of each of these pyramids are directed to, and bounded by the cortex: the apex forms a *papilla*, which projects into one of the calices, produced by the branching of the pelvis of the ureter. Each of these pyramids, with the cortical substance in immediate relation to it, forms one of the primary lobules of the kidney, and is homologous therefore with one of the renules of the ox's kidney.

If the surface of a section through one of these pyramids be examined with a pocket lens, it will be seen to possess a striated appearance, and the striæ radiate from the papillary apex to the base of the pyramid. These striæ indicate that the pyramid is principally composed of tubes, the *tubuli uriniferi*. The urinary tubules commence at the papilla, on the surface of which the openings of about twenty of these tubes may be seen. The kidney is therefore a tubular gland.

In order to trace out the arrangement of the tubes, it will be necessary to examine thin sections with higher powers of the microscope. If we start with a tubule, where it opens on the surface of a papilla, as the *ductus papillaris*, and trace it into a medullary pyramid, we find that in its course it bifurcates repeatedly at acute angles into smaller branches, which slightly diverge from each other, and ultimately reach the base of the pyramid. These branching tubes are called the *straight* or *collecting* tubes; they then enter the cortex in bundles, which are

named the *medullary rays*, or the *pyramids of Ferrein*. In the cortex the tubes extend towards the surface of the kidney preserving their straight course, when they again branch, and the branches, which are at first dilated and tortuous, are named the *intermediary* or *junctional* tubes. Each intermediary tube then diminishes in calibre, and descends for a variable distance into the medullary pyramid, where it turns on itself, forms a loop, known as the *looped tube* of Henle, and re-enters the cortex as the ascending limb of the looped tube. In the cortex the ascending tube becomes continuous with a dilated and very tortuous tube, which opens, as was clearly shown by Bowman, into a dilated and closed sac, named *Bowman's capsule*. The junction of this capsule with the tortuous tube is marked by a constricted *neck*, and the tortuous tube is called the *convoluted* tube.

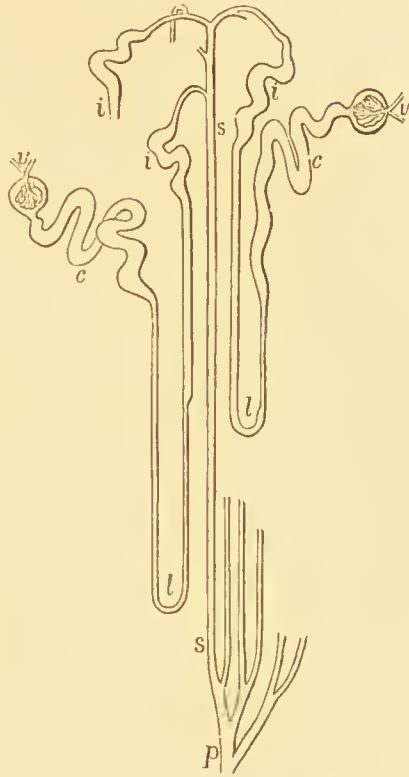


FIG. 220.—Scheme of the arrangement of the Urinary tubules. *p*, the ductus papillaris; *s*, the branching straight tubes; *i*, *i*, intermediary tubes; *l*, *l*, looped tubes with ascending and descending limbs; *c*, *c*, convoluted tubes ending in Bowman's capsules; *v*, *v*, vas afferens and efferens.—From Ludwig.

The convoluted tubes and Bowman's capsules occur only in the cortex of the kidney; and they, with their contents, are the characteristic structures seen in it on microscopic examination. Strictly speaking, Bowman's capsule is the dilated commencement of a urinary tubule, which possesses the long and complicated course described as the convoluted, looped, intermediary and straight tubules, before it opens on the surface of the papilla at the ductus papillaris. The cortex of the kidney contains many thousands of Bowman's capsules. The intermediary tubes are also found only in the cortex. The looped and straight tubes occur both in the cortex and in the medullary pyramids. The diameter of the several kinds of tubes is not uniform. The straight tubes within the papilla are from $\frac{1}{240}$ th to $\frac{1}{450}$ th of an inch, that of their branches $\frac{1}{600}$ th, which is also about the diameter of the convoluted tubes. The looped tubes are considerably smaller, and the limb, which descends from the intermediary tube into the medullary pyramid, is wider than that which ascends from the pyramid to the convoluted tube. Bowman's capsules vary in diameter from $\frac{1}{120}$ th to $\frac{1}{250}$ each.

The wall of each tube is formed of a delicate membrane, or tunica propria. Generally speaking, the membrane is extremely thin and homogenous, with occasional nuclei, but Frey states that in the looped and convoluted tubes it is thicker than in the straight tubes; and in the ductus papillaris, the tunica propria is said to be absent. The tubes are lined by an epithelium, which varies in its character in different localities. In the ductus papillaris the epithelium consists of low columns. In the straight tubes it is much more distinctly columnar. In the inter-

mediary and convoluted tubes, it consists of a clouded mass of nucleated protoplasm, which presents a very imperfect differentiation into individual cells; this mass so fills up the tube as to leave a very small lumen. In the looped tubes the epithelium is flattened, and with distinct ovoid nuclei, which project towards the lumen of the tube; but from the observations of W. Pye, cubical epithelium occurs in the wider parts of the looped tube, and where the tube joins the intermediary tube, the cells are more elongated, and the lumen of the tube is diminished.

The intervals between the tubes both in the medullary and cortical parts of the kidney, are occupied by connective tissue and blood-vessels. The connective tissue stroma within the kidney was first described by Bowman and Goodsir. In the medullary region this tissue is distinctly fibrillated, but in the cortex the fibrillated tissue is very sparing, and the connective tissue stroma of the gland consists essentially, as Arnold Beer pointed out, of spindle-shaped and stellate corpuscles.

The blood-vessels of the kidney consist of the renal artery and renal vein, with their capillaries.

The renal artery arises from the side of the abdominal aorta, and runs transversely outwards to the hilus of the kidney, where it divides into several branches before entering the gland. Sometimes two, or even three, renal arteries arise independently from each side of the aorta. The branches of the renal artery enter the hilus between the calices of the ureter; they penetrate and divide into smaller branches within the columns of Bertin, or prolongations of cortical substance that lie between the sides of the medullary pyramids. When they reach the level of

the bases of the pyramids, they arch between them and the cortex, and form a series of arterial arcades, which have but little communication with each other. From these arterial arches numerous branches pass outwards into the cortex. They run almost straight towards its free surface,

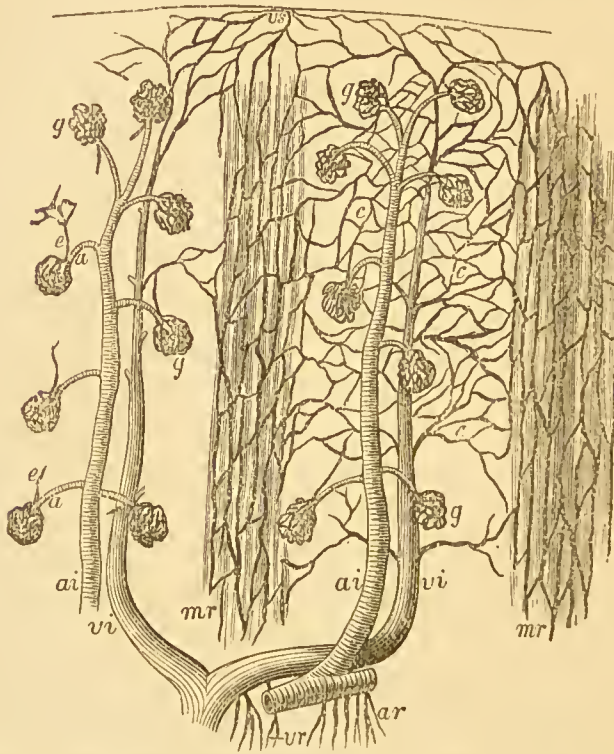


FIG. 221.—Vertical section through the cortex of the Kidney. *ai, ai*, interlobular arteries; *a, a*, vasa afferentia; *g, g*, glomeruli; *e, e*, vasa efferentia; *c, c, c*, capillaries of the cortex, partly surrounding the convoluted tubules, and partly surrounding the straight tubules of the medullary rays, *mr, mr*; *vs*, stellate vein on the surface of the cortex; *vi, vi*, interlobular veins; *ar*, the straight arteries, and *vr*, the straight veins of the medullary pyramids.—From an injection by T. A. Carter. + 40.

and lie in the intervals between adjoining medullary rays. They are named *interlobular arteries*, and give off both collaterally and terminally short branches, called *vasa afferentia*, and at the surface of the kidney supply small

branches to its fibrous coat. Each *vas afferens*, invested by its sheath of connective tissue, passes to a Bowman's capsule in its immediate neighbourhood, the wall of which it appears to perforate at one pole. It divides in the capsule into from four to eight branches, which subdivide into capillaries, and form a vascular tuft or *glomerulus*, called the *Mulpighian tuft*, situated opposite to the junction of the capsule with the urinary tubule. From the capillaries of the tuft a vessel arises, which

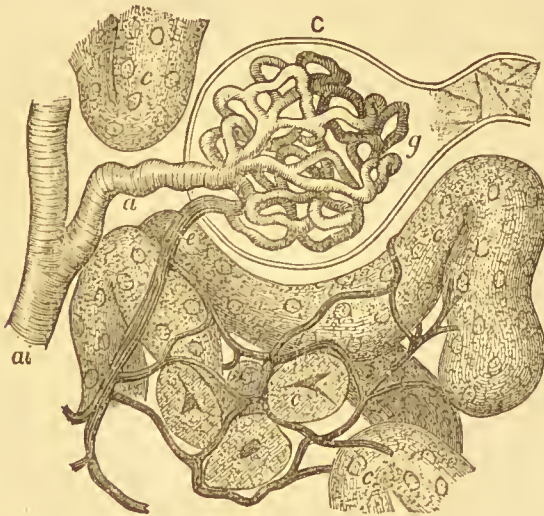


FIG 222—Section through the cortex of the kidney. *C*, Bowman's capsule containing *g*, a glomerulus; *ai*, interlobular artery; *a*, *vas afferens*, and *e*, *vas efferens*; *c*, *c*, *c*, convoluted tubules surrounded by a capillary plexus springing from the efferens. In order to show the glomerulus, the cellular contents of Bowman's capsule have not been represented. $\times 300$.

passes out of Bowman's capsule as the *vas efferens*. It usually emerges quite close to the *vas afferens*, but at once diverges from it, and after a short course ends in a network of capillaries, distributed between and around the convoluted tubules (fig. 222).

The wall of Bowman's capsule is extremely thin, and according to Ludwig consists of a layer of flattened cells, on the outer surface of which is a little connective tissue. These cells form the lining epithelium of the capsule. The glomerulus occupies the interior of the capsule, but is not adherent to its wall. By most observers it is believed that the epithelial lining of the capsule is reflected on the surface of the glomerulus, to form a covering for it, consisting of granulated cells, smaller and somewhat thicker than those of the epithelial lining of the capsule. By other observers again, the demonstration of the cellular covering of the glomerulus is not considered to have been satisfactorily established. From the observations of Seng and of Walter Pye, not only the entire glomerulus, but the several subdivisions of the tuft, are in the foetal kidney invested by epithelial cells. As Bowman's capsule is produced by a folding of the wall of the foetal tubule over the glomerulus, the cells which cover the tuft are the epithelium of the foetal urinary tubule.

The capillaries, which lie in the stroma between the convoluted tubules, form a network around these tubules, which joins the capillary network around the straight tubules of the medullary rays, so that the capillaries form a continuous plexus throughout the cortex. According to Ludwig, lacuniform spaces, often filled with fluid, intervene between the wall of the capillaries and that of the urinary tubes. Minute veins arise from this capillary plexus. Those that arise from the capillaries surrounding the tubules at the free surface of the cortex, are arranged in a star-like manner, and form the *venæ stellatae*, which also receive small veins from the fibrous

coat. The stellate veins give origin to larger veins, which pass through the cortex towards the medulla, along with the interlobular arteries, and receive in their course numerous small veins from the cortical capillary plexus. They unite near the bases of the medullary pyramids into larger veins, which form venous arcades (fig. 221).

But the renal artery also gives branches to the medullary pyramids of the kidney, and *perforating* branches, which pierce the fibrous coat, and anastomose in the surrounding fat with the extra-peritoneal system of arteries (p. 433). The branches to the pyramids are named *arteriæ rectæ*, and in part arise directly from the branches of the renal artery, situated near the sides and bases of the pyramids, and in part consist of vasa efferentia, proceeding from those glomeruli in the cortex, which lie close to the medulla. In the pyramids the *arteriæ rectæ* divide into capillaries, which form a plexus in the stroma and surround the straight and the looped tubes. To some extent, therefore, but not altogether, the circulation of blood to the medullary pyramids is independent of that in the cortex. Veins called *venulæ rectæ* correspond to the *arteriæ rectæ*, and run from the apex to the base of a pyramid, where they end in the larger veins of the cortex. These join to form the venous trunks, which accompany the arteries in the columns of Bertin to the hilus, where they unite to form the renal vein, which lies in front of the artery, and opens into the inferior cava.

Lymphatic vessels emerge from the hilus of the kidney and from its fibrous coat. The superficial lymphatics arise, according to Ludwig, from lymph-spaces, situated between the convoluted tubes of the cortex. The origin

of the deeper lymphatics is not known. Nerves accompany the blood-vessels into the kidney : they arise from the renal plexus of the sympathetic nerve, which is joined by the smallest splanchnic nerve.

THE URETERS.

The Ureters are two tubular ducts, which convey the urine from the kidneys to the bladder. Each ureter arises at the hilus of its kidney from the dilated pelvis formed by the junction of the calices. The ureter is about fifteen inches long, and descends behind the peritoneum covering the posterior wall of the abdomen into the pelvis, where it runs forward to reach the base of the bladder, the wall of which it pierces obliquely before opening into its cavity by a slit-like orifice (fig. 218).

Structure.—The ureter possesses several coats. The external is a tunica adventitia formed of connective tissue : within this is a muscular coat of non-striped fibre arranged in three layers, of which the internal and external layers are longitudinal, and the middle layer is circular. The internal coat is a mucous membrane, and between it and the muscular coat is the submucous coat. The epithelium covering the mucous coat resembles that of the bladder to be immediately described. Where the calices embrace the papillary apices of the medullary pyramids of the kidney, the tunica adventitia of the cortex is continuous with the adjacent fibrous coat of the kidney, and the mucous lining is prolonged upon the surface of the papilla. The longitudinal muscular fibres disappear near the attached border

of the calyx, but the circular fibres have been described by Henle as forming a circular muscle around the papilla, where the mucous membrane is reflected on it.

The coats of the ureter receive blood through small branches of the renal, spermatic, and inferior vesical arteries. Nerves from the spermatic and hypogastric plexuses also pass to them.

URINARY BLADDER.

The Urinary Bladder is the reservoir in which the urine collects prior to being expelled along the urethra. It varies in size, shape, and consequently in position, with the amount of urine it contains. When quite empty it lies in the cavity of the pelvis, behind and above the pubic bones and symphysis. When moderately full it rises slightly above the pubic symphysis into the hypogastrium, and, as its distension increases, it ascends still higher into this region. The empty bladder is flattened in form; when moderately full it is rounded; when much distended it is ovoid, and its longest axis is directed from above, downwards and backwards.

The following parts may be recognized in a well-distended bladder, a base, an apex, an anterior a posterior and two lateral *surfaces*, and a cervix or neck. Its *base* or *fundus* is directed backwards towards the second part of the rectum, from which it is separated, in the male, by the vesiculæ seminales, and the recto-vesical layer of the pelvic fascia. Its *apex* is directed forwards to the hypogastrium, and from it a fibrous cord, the obliterated *urachus*, proceeds towards, and often as far as the navel. The

anterior surface, directed downwards and forwards, is in relation to the pubic bones and symphysis, and to the anterior wall of the abdomen, in the region of the hypogastrium, to all of which it is attached by loose areolar tissue. The *posterior surface*, directed upwards and backwards, is covered by peritoneum, and is separated from the first part of the rectum by the recto-vesical pouch, in which some coils of the small intestine may be lying. The *lateral surface* is partially covered by peritoneum, and has the vas deferens and obliterated hypogastric artery running along it. The *neck* is situated immediately in front of the base, and gives origin to the urethra; it is the lowest or most depending part of the bladder, and in the male is embraced by the base of the prostate gland.

Passing to the bladder are two important membranes, which, together with its vessels and ducts, retain it in position. These membranes are the peritoneum and the pelvic fascia.

The *Peritoneum* forms the *false ligaments* of the bladder, and is arranged with reference to it as follows:—The peritoneum is reflected from the rectum to the posterior surface of the bladder as two folds, named the *posterior false ligaments*, which form the lateral boundaries of the recto-vesical pouch, or pouch of Douglas. Having reached the bladder the peritoneum covers its posterior surface, and extends for a variable distance over the base or fundus; in the empty bladder the peritoneal covering for the base is more extensive than when the bladder is distended. The peritoneum passes over the sides of the bladder as far as the obliterated hypogastric arteries, when it is reflected to the side walls of the pelvis as the *lateral false ligaments*.

It also extends to the apex of the bladder, where it is reflected to the anterior wall of the abdomen, along the line of the urachus, as the *superior* or *false ligament*. The anterior surface of the bladder is not covered by the peritoneum, so that when the bladder rises above the pubes it can be opened without injuring that membrane. The cervix likewise has no relation to the peritoneum. The absence of a peritoneal covering, on the anterior part of the base of the bladder, enables the surgeon to puncture the bladder from the rectum without injuring the serous membrane.

The *Pelvic Fascia* gives rise to the *true ligaments* of the bladder. As this important fascia is intimately related, not only to the bladder, but to all the other pelvic viscera, it will be advisable to examine its arrangement generally. The pelvic fascia is attached to each side of the pelvic brim, and to the back of the bodies of the pubic bones; it descends into the pelvis on the inner surface of the internal obturator muscle, is prolonged downwards as far as the spine and tuberosity of the ischium, to both of which it is attached, and is often called the obturator fascia. Behind the spine of the ischium the fascia is prolonged backwards as a thin membrane on the anterior aspect of the pyriformis muscle, sacral plexus of nerves, and great sciatic foramen. It lies behind the internal iliac artery and its branches, and is pierced by the gluteal, sciatic, and pudic arteries in their course to the great sciatic foramen. From the relation of this part of the fascia to the anterior, lateral, and posterior part of the pelvic wall, it may appropriately be called the *parietal* division of the pelvic fascia.

On a line with the spine of the ischium and the back of

the pubis the fascia gives rise to a strong band, which passes inwards to the pelvic viscera, and may appropriately be called the *visceral* division of the pelvic fascia. Where this visceral band is given off the fascia is whiter and more opaque, and is known as the *white line*. The most anterior part of the visceral division of the fascia passes backwards, in the male, to the upper surface of the prostate gland, forming the *pubo-prostatic ligament*, and is then reflected on the front of the bladder as its *anterior true ligament*. The lateral portion of the visceral division passes inwards, and, in the male, splits into three layers, the most superior of which reaches the side of the bladder to form its *lateral true ligament*; the middle layer goes between the base of the bladder and the rectum as the *recto-vesical* layer of the fascia; whilst the most inferior layer forms the *rectal* layer, which passes under the second and third parts of the rectum and ensheaths the levator ani. The pubo-prostatic ligament gives rise to the fibrous capsule of the prostate gland, and the recto-vesical layer ensheaths the vesiculæ seminales, and the corresponding parts of the vasa deferentia, which lie between the rectum and bladder.

The *Urachus*, which is prolonged from the apex of the bladder to the anterior wall of the abdomen, is a fibrous cord, representing, in the adult, an embryonic canal, connecting the bladder with the extra-abdominal part of the allantois. As development advances the allantois disappears and the urachus shrivels up into a fibrous cord, sometimes called the *middle vesical ligament*. Cases sometimes occur in which the urachus remains pervious for a short distance, and communicates with the bladder.

Structure of the Bladder.

The Bladder possesses four coats—serous, muscular, sub-mucous, and mucous.

The *serous* or *external coat* furnishes only a limited investment to the bladder, as has already been described.

The *muscular coat* is formed of fasciculi of non-striped fibres arranged in three layers. The fasciculi of the *external longitudinal* layer arise from the posterior surface of the body of the two pubic bones, and from the adjacent part of the prostate gland and its capsule; they reach the anterior surface of the bladder, ascend as far as its apex, and then pass downwards on its posterior surface and base, as far as the neck of the bladder and the under surface of the prostate. This layer has been named the *detrusor urinæ* muscle. The *circular layer* lies next the external longitudinal layer, and consists of fasciculi which, though to some extent placed transversely to the long axis of the bladder, are for the most part arranged obliquely. At the neck of the bladder they increase in numbers and form the *sphincter vesicæ* muscle. Pettigrew has described the external longitudinal and circular layers as forming together a series of figure-of-8 spiral loops. The *internal longitudinal* layer was first described by Ellis, and consists of slender fasciculi arranged longitudinally in relation to the sub-mucous coat. The muscular coat by its contraction expels the urine from the bladder into the urethra. In cases where the urethra is obstructed by stricture, or by enlargement of the prostate, the muscular coat becomes greatly hypertrophied.

The *sub-mucous coat* forms a layer of vascular connective tissue between the muscular and mucous coats. It is

almost absent in the region of the trigone of the bladder. The *mucous* or *internal coat* is thrown into folds or *rugæ* in the empty bladder, owing to the laxity of the sub-mucous coat, but, when the bladder is distended, the mucous coat is smooth. The mucous lining of the base of the bladder is, however, smooth, even in the contracted bladder, over a triangular surface, bounded behind by a line drawn transversely between the two uretral openings, and on each side by a line drawn from the uretral orifice to the opening of the urethra. This triangular surface is called the *trigone* of the bladder, and it corresponds, internally, to a triangular region on the outside of the base of the bladder, bounded on each side by the vesicula seminalis and vas deferens, in front by the prostate gland, and behind by the line of reflection of the peritoneum from the rectum to the bladder.

The free surface of the mucous membrane is covered by a stratified epithelium, the cells of which are multiform in



FIG. 223.—Epithelial cells from the mucous membrane of the Bladder. Those in the upper row are the superficial squamous cells; those in the lower row are the peculiar cells of the middle stratum.

shape. The superficial stratum consists of large flattened cells with large distinct nuclei; the middle stratum consists of pear-shaped cells, the broad ends of which are in

contact with the deep surface of the cells of the superficial stratum, whilst the narrow end is prolonged between the cells of the deepest stratum, which are irregularly oval or rounded cells, with sometimes a slender process prolonged between the narrow ends of the pear-shaped cells. Small racemose glands open on the surface of the mucous membrane, especially in the region of the cervix; their excretory ducts are lined by columnar epithelium.

The *arteries* which supply the bladder with blood are the superior vesical branch of the hypogastric artery, and the inferior vesical branch of the internal iliac, which are distributed in the muscular coat, and give rise to a capillary network in the mucous membrane. The veins pass to the vesical venous plexus. *Lymphatics* occur in the walls of the bladder, especially in the trigone, in which region solitary lymph follicles are also found; the lymph vessels join the lymphatics which accompany the internal iliac artery. The nerves proceed from the hypogastric plexus of the sympathetic and from the sacro-coccygeal plexuses. F. Darwin has traced slender plexuses with nerve cells accompanying the blood-vessels.

THE URETHRA.

As the Urethra in the *male* is the excretory duct for both the urine and the secretion of the genital glands, the consideration of its anatomy will be deferred until the next chapter.

The urethra in the *female*, conveys only the urine. It is a tube about $1\frac{1}{2}$ inch long, which, arising as a funnel-shaped tube from the neck of the bladder, passes downwards and forwards under the pubic arch to open on the vulva, between the nymphæ, immediately above the orifice of the vagina, and about an inch below the clitoris. It is imbedded in the anterior wall of the vagina, and is in a part of its course surrounded by the fibres of the compressor urethræ muscle. It is lined by a mucous membrane, continuous with that of the bladder, which is elevated into longitudinal folds. This membrane is covered by a stratified squamous epithelium, and mucous glands open on its surface. The wall of [the urethra, external to the mucous membrane, is very vascular, and contains large veins; the vessels are mingled with connective tissue and a circular layer of non-striped muscular fibres.

CHAPTER XII.

REPRODUCTIVE SYSTEM.

The Reproductive System consists of organs, the office of which is to provide for the perpetuation of the race. These organs differ from each other in the two sexes : but, both in the male and female, the materials essential for the reproductive process are the products of two genital glands, and are conveyed along a system of tubes and passages.

MALE ORGANS OF REPRODUCTION.

The essential organs of Reproduction in the male are the Testicles, or *genital glands*, in which the semen is secreted. From each testicle a duct proceeds, called Vas Deferens, which conveys the semen to the Urethra. The male urethra is for the greater part of its extent contained in the Penis, or organ of copulation. Certain accessory structures to the male generative apparatus are named Vesiculæ Seminales, Prostate Gland, and Cowper's Glands.

THE TESTES AND SPERMATIC CORDS.

The Testes or Testicles are two glands situated in the Scrotum, and the Spermatic Cord is the collection of vessels, nerves, and the excretory duct connected with each testis. As the testicle and the cord in the scrotum are invested by several structures, technically called their *coverings*, these will first be described.

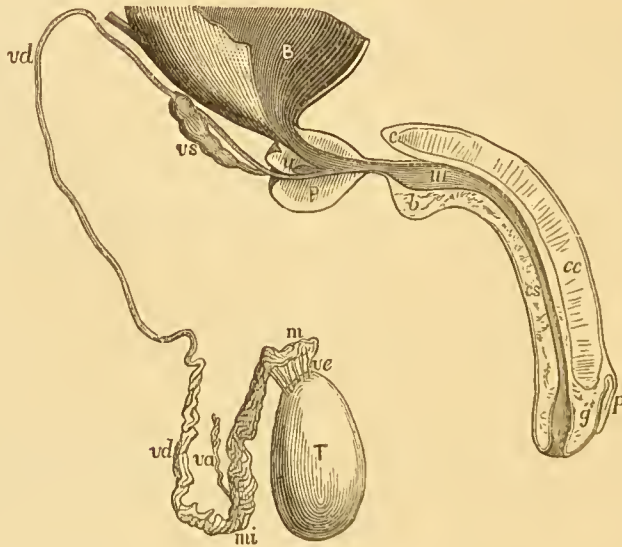


FIG. 224.—General view of the Male organs of generation. T, testicle; ve, vasa efferentia; m, globus major, and mi, globus minor of epididymis; va, vas aberrans; vd, vd, vas deferens; vs, vesicula seminalis; p, prostate gland, with e, the vesicula prostatica and the common ejaculatory duct piercing it to open into the urethra; ur, the urethra; b, the bulb; cs, corpus spungiosum; cc, corpus cavernosum; g, glans penis; p, prepuce; B, bladder.

The SCROTUM consists of a purse-like fold of the integument, which hangs pendulous between the two thighs. Its skin is coloured by pigment, and is covered with hairs ;

it presents a wrinkled appearance, though it may become smooth and lax in hot weather, and in a debilitated state of the body. Beneath the skin is a thin layer of superficial fascia of a pale reddish tint, which contains a large quantity of non-striped muscle, and is devoid of fat. This layer is called the *dartos muscle*, and through its contraction the corrugated condition of the skin of the scrotum is produced. The scrotum is divided into two lateral halves, by a median septum, into which the dartos fibres are prolonged. The position of this septum is marked, on the surface of the scrotum, by a median line or raphé, which is continuous behind with the raphé of the perineum. Each half of the scrotum contains a testicle and a spermatic cord, and each testicle with its cord is enveloped by four special coverings, which are arranged from without inwards, as follows :—

The *spermatic fascia* is a thin fibrous membrane, continuous above with the flattened tendon of the external oblique muscle of the abdomen, at the external or superficial abdominal ring. The *cremaster muscle* consists of fasciculi of striped muscle, continuous above with the internal oblique muscle of the abdomen : the fasciculi form a loop-like arrangement over the testicle and spermatic cord, and are attached together by intermediate areolar tissue, so as to form the cremasteric covering or fascia. The *infundibuliform fascia* is a very delicate layer of fibrous membrane, continuous above with the fascia transversalis of the abdomen, at the internal or deep abdominal ring. The *tunica vaginalis* is a serous membrane, the outer surface of which is connected by areolar tissue to the infundibuliform fascia. Its inner surface is smooth, and

covered by a layer of endothelium, which is reflected on the testicle, so as to form a smooth visceral layer, similar to the serous epicardium which envelopes the heart. The visceral layer of the tunica vaginalis reaches the testicle at its posterior border, where it is in contact with the epididymis: it partially invests the epididymis, and forms a pouch between that body and the testicle. The tunica vaginalis is also prolonged for a short distance upwards along the spermatic cord, where it forms a closed sac. Sometimes a thread-like band may be seen in the cord above the tunica vaginalis, and extending upwards towards the peritoneum. This band indicates the position of a tubular connection, at one time existing between the peritoneum and tunica vaginalis.

To understand why the testicle and spermatic cord possess these several coverings, it should be stated that the gland is originally formed in the abdomen, where it has a peritoneal envelope; but that it descends through the wall of the abdomen into the scrotum, and carries along with it a covering from each of the structures in that wall, with which it comes in contact in the course of its descent.

Owing to its development in the abdomen, it derives its vessels and nerves from the vascular and nervous trunks situated in that cavity. As it descends through the wall of the abdomen into the scrotum, these structures are elongated, and descend with it, and together with the vas deferens, or excretory duct of the testicle, form the spermatic cord. The cord, after it has passed through the wall of the abdomen, like the testicle, is enveloped by the spermatic, cremasteric, and infundibuliform fasciæ. The

cord consists of the spermatic artery, a branch of the abdominal aorta : of the spermatic veins, which form a well-marked plexus, called the *pampiniform plexus* : of lymphatics, which communicate with the iliac and lumbar lymphatics : of nerves which are derived from the aortic plexus of the sympathetic, and accompany the spermatic artery, and of the vas deferens. But the vas deferens has a small special artery accompanying it, a branch of the superior vesical artery, and the coverings of the cord receive the cremasteric branch of the epigastric artery. The genital branch of the genito-crural nerve supplies the cremaster muscle.

The testicle is suspended by the spermatic cord and its coverings in the scrotum, in which it lies obliquely ; the left testicle being usually a little larger and more dependent than the right. It is ovoid in form, compressed laterally ; and possesses two lateral surfaces, two borders, and two extremities. It is about $1\frac{1}{2}$ inch in its vertical diameter, $1\frac{1}{4}$ inch in its antero-posterior diameter, and half an inch from side to side. The whole of the exterior of

the gland, except the posterior border, is smooth, and invested by the visceral layer of the peritoneum. The



FIG. 225.—The Testicle, as seen from behind; *m*, globus major; *b*, the body, and *mi*, globus minor of epididymis; *vd*, vas deferens.

posterior border gives attachment to the epididymis, which is the convoluted commencement of the vas deferens. The *epididymis* consists of an upper end, the *globus major*, or head of the epididymis; a lower end, or *globus minor*, and an intermediate part, the *body* of the epididymis. From the *globus minor* the vas deferens proceeds. The epididymis is to a large extent covered by the visceral layer of the tunica vaginalis, but at its upper and lower ends it is closely united to the testicle. Between the *globus major* of the epididymis and the upper end of the testicle is a small pedunculated body, called the *pedunculated hydatid of Morgagni*.

Structure of the Testis and Epididymis.

The Testicle, in addition to its serous envelope, is invested by a dense fibrous coat, the *tunica albuginea*, which gives off along the posterior border of the gland a strong prolongation into its interior, named the *corpus Highmorianum* or *mediastinum testis*. But, in addition, slender processes arise, generally from the inner surface of the tunica albuginea, which pass inwards to the *mediastinum testis*, and collectively form the *septa testis*. Through this arrangement the interior of the gland is divided into a number of lobular compartments, occupied by the seminal tubes. The tunica albuginea, the *mediastinum testis*, and the *septa testis* are formed of connective tissue. Kölliker states that non-striped muscular tissue occurs in the tunica along its posterior border, and in the *septa testis*. Blood-vessels, continuous with the spermatic artery and veins, are also distributed over its inner surface,

and along the septa, so as to form what Astley Cooper called the *tunica vasculosa*.

The *tubuli seminiferi*, or seminal tubules, constitute the proper secreting substance of the testicle. They are lodged in the intervals between the septa testis, and

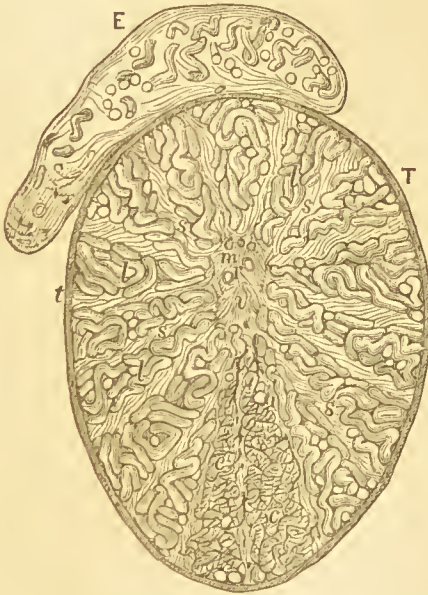


FIG. 226.—Transverse section through the Testicle and Epididymis of an infant. T, the testicle; *l*, tunica albuginea; *s*, *s*, septa testis; *l*, *l*, lobes of testis containing seminal tubules; *m*, mediastinum; *v*, vasa recta; *r*, rete testis; *c*, capillaries surrounding seminal tubules; E, epididymis. $\times 6$.

form conical masses of a reddish-yellow soft material, named the *lobes* of the testis. Each lobe is composed of from two to four or six highly convoluted tubules; and as there are from 250 to 400 lobes in the testis, the number of seminal tubules ranges probably from about 800 to 1000. The convoluted tubules in a lobe are connected together by delicate areolar tissue and capillary blood-

vessels. When these are torn down by dissecting with needles under water or spirit, the tubes may be untwisted and seen to have an average length of $2\frac{1}{4}$ feet, and a diameter of from $\frac{1}{150}$ th to $\frac{1}{200}$ th of an inch. The tubes begin either with blind ends or anastomosing loops. They become straighter as they approach the mediastinum, where they join and form the *vasa recta*, about twenty in number, which possess an average diameter of about $\frac{1}{80}$ th of an inch. When within the mediastinum the straight tubes unite to form a network, the *rete testis*. From the rete testis from twelve to twenty tubes arise, which pierce the tunica albuginea, at the upper end of the testicle under cover of the head of the epididymis, and form the *vasa efferentia*. As in each vas efferens the tube again becomes convoluted, and forms a conical mass, the name *coni vasculosi* has been applied to the series of vasa efferentia. The length of the convoluted vas efferens in each conus is, when unravelled, about seven inches. The several vasa efferentia unite together to form the epididymis; the tube of which is coiled upon itself to form the globus major, body and globus minor of that canal. From the tube in the globus minor the vas deferens arises. The length of the tube of the epididymis, when unravelled, is about twenty feet, and its diameter varies from about $\frac{1}{70}$ th to $\frac{1}{90}$ th inch.

The tubuli seminiferi, within the lobes of the testis, have a wall, or membrana propria, formed of layers of polygonal, nucleated, flattened cells. Outside this wall is a very delicate areolar tissue, in which is situated, not only the network of blood capillaries surrounding the seminal tubes, but the lymph-spaces and lymph capillaries

that give origin to the lymphatics of the testicle. The bundles of intertubular connective tissue are, according to Mihalkovics, invested by flat endothelial-like cells, and the chinks between these bundles are apparently the lymph-spaces. The wall of the vasa recta and rete testis also consists of flattened cells. The wall of the vasa efferentia is thicker and more highly differentiated, for it consists not only of connective tissue, but of non-striped muscle, arranged both circularly and longitudinally. The wall of the epididymis possesses a similar structure.

The tubuli seminiferi are occupied by cells. Before the period of puberty these cells are inactive: their protoplasm is granulated and possesses nuclei, but the outlines of the individual cells are obscure. When the testicle is actively engaged in the secretion of semen, the contents of its tubes assume other characters, and give rise to the formation not only of the fluid part of the semen, but of the peculiar spermatic filaments or spermatozoa.

The *spermatozoa* are microscopic thread-like filaments from $\frac{1}{400}$ th to $\frac{1}{500}$ th inch long. At one end the thread is dilated into an ovoid or pear-shaped body, about $\frac{1}{600}$ th inch long, called the head of the spermatozoon, whilst the rest of the structure forms the body and filamentous tail. The spermatozoa are developed within the specially modified spermin cells or *spermato-blasts*, occupying the seminal tubes, the nuclei of which have greatly increased in numbers. From the recent observations of Neumann and Krause, it would appear that the spermato-blasts consist of a network of nucleated protoplasm, in part attached to the wall of the seminal tube, and in part projecting into its

lumen, so as to form a series of projecting columns of nucleated protoplasm. From the free ends of these columns long filaments protrude, which look at first like cilia, but are seen on further examination to be the attenuated tails of the spermatozoa. The protoplasm of the spermato-blasts is colourless, granulated, and easily torn. The nuclei, situated near the attached ends of the columns, are large and oval, and contain a nucleolus. Those nuclei which lie near the free ends of the columns are specially modified to form the heads of the spermatozoa, and the protoplasm immediately surrounding them becomes continuous with the nucleus, and differentiates into the body and filamentous tail of the individual spermatozoa. As the development proceeds, the spermatozoa liberate themselves from the spermato-blasts, and become free in the seminal tube. In the meshes of the network formed by the spermato-blasts, numerous distinct cells, capable of being separated from the network, are situated. They are often globular in form, and contain one or more nuclei. The precise function of these cells has not been determined, and they have been named indifferent sperm cells; it is not improbable that they are spermato-blasts in the earlier stages of formation. It is not until the spermatozoa reach the rete testis, or the vasa efferentia, that they become entirely free from the protoplasm of the spermato-blasts, in connection with which they were formed, when they then assume a power of active movement.

The indifferent sperm cells and the spermato-blasts represent the epithelium of the seminal tubes in the lobes of the testis and in the rete testis. In the vasa efferentia and epididymis, as far as the globus minor, the seminal ducts

possess a distinct lining of columnar and ciliated epithelial cells, but the cilia disappear in the globus minor.

The blood and lymph vessels and the nerves of the testicle are continuous with those to which reference has been made in the description of the spermatic cord. According to Letzerich, the nerve fibres pierce the proper wall of the seminal tubules, and end in clumps of protoplasm, having a direct relation to the sperm cells.

Haller described a tubular diverticular prolongation from the globus minor of the epididymis by the name of *vas aberrans*. It varies in length from $1\frac{1}{2}$ inch to 14 inches, and lies parallel to and between the epididymis and the vas deferens, and is convoluted like the former tube. In structure it resembles the vas deferens.

Giraldès discovered in 1857 a small body situated beneath the tunica vaginalis, covering the front of the spermatic cord, immediately above the head of the epididymis, which has been named the *parepididymis*, or *organ of Giraldès*. It varies in size from a mere speck to a body 4 or 5 lines long, and consists of small convoluted tubes lined with a squamous epithelium.

The VAS DEFERENS is the tubular duct, about two feet in length, which conveys the semen from the epididymis to the urethra. It arises from the globus minor of the epididymis, with the convoluted tube of which it is continuous. It is tortuous at its commencement, and ascends behind the epididymis, then enters the cord, and is continued upwards, behind the spermatic vessels, through the inguinal canal, as far as the internal or deep abdominal ring. Here it leaves the spermatic vessels, curves round the outer side of the deep epigastric artery, and sinks into

the pelvis. It then reaches the side of the bladder, along which it descends to reach the base of the bladder; in its course it crosses the obliterated hypogastric artery, and goes between the ureter and the bladder. At the base of the bladder it inclines to the inner side of the vesicula seminalis, and, near the base of the prostate gland, it joins the duct of the vesicula to form the common ejaculatory duct. The vas is sacculated and tortuous at the base of the bladder, but in the greater part of its extent it is a cylindrical tube, with dense, firm walls, so that it feels like a piece of whip-cord.

It possesses an external coat of connective tissue; within which is a thick coat partly formed of fibro-elastic tissue and partly of non-striped muscle, arranged both longitudinally and circularly. It is lined by a mucous membrane, which is covered by columnar epithelium. The fibro-muscular coat of the sacculated part of the vas is much thinner, and branched tubular glands open on the mucous surface. Owing to the thickness of its wall in the greater part of its extent, the vas deferens possesses a comparatively small lumen.

The VESICULE SEMINALES are two sacculated reservoirs for the semen, situated between the base of the bladder and the rectum. Each vesicula is about 2 inches in length, and consists of a convoluted tube, about 6 inches long, which forms at one end a *cul-de-sac*, but at the opposite end becomes attenuated into a slender duct, which joins the vas deferens, to form the common ejaculatory duct. When the convoluted tube of the vesicula is unravelled, it is seen to possess several short diverticula opening into it. The structure of the wall of the vesicula

corresponds with that of the sacculated portion of the vas. The tubular glands in its wall pour their secretion into it, so that its fluid contents consist not only of semen, but of the special secretion of these glands.

The COMMON EJACULATORY DUCTS are two in number, each being formed by the junction of the vas with the duct of the vesicula of its own side. Each common duct is about one inch long. They lie close together, and pass forwards, between the middle and lateral lobes of the prostate gland, to open in the prostatic part of the urethra, on the summit of the colliculus seminalis, one on each side of the mouth of the prostatic vesicle. Their walls are much thinner than those of the vesiculæ seminales, the diminution being especially marked in the fibro-elastic coat.

The excretory apparatus of the testicle, known by the several names of vasa efferentia, epididymis, vas deferens, and common ejaculatory duct, is characterized by the extraordinary length and convoluted character of its tube. Whilst the actual distance between the testicle and the prostatic part of the urethra, in which the excretory apparatus ultimately opens, is not more than a few inches; the length of the tube which conveys the secretion into the urethra amounts to many feet. The inference which may naturally be drawn from this arrangement is, that the secretion of the testis passes but slowly from the gland to the vesiculæ seminales and urethra, and probably undergoes a considerable amount of elaboration in its course.

THE PROSTATE GLAND.

The Prostate Gland is a muscular and glandular body which surrounds the commencement of the urethra (fig. 224). It is shaped like a chestnut, and measures $1\frac{1}{4}$ inch from base to apex, $1\frac{1}{2}$ inch in its transverse diameter, and something less than an inch in thickness. It lies behind the symphysis pubis, and in front of the rectum. Its direction is obliquely from above downwards and forwards, and its base, or highest part, is in relation to the neck of the bladder and the common ejaculatory ducts, whilst, from its depending truncated apex, the membranous part of the urethra emerges. Its anterior surface is attached to the pubes by the pubo-prostatic ligaments of the pelvic fascia, and the anterior parts of the lateral true ligaments of the bladder; whilst the most anterior fibres of the levator ani muscle passes to each of its sides, and form the *levator prostatae* muscle.

The prostate is divided into three lobes, a median and two lateral. The lateral lobes make up the chief part of the gland, and are separated behind by a median notch. The middle lobe is of small size, and lies below the prostatic part of the urethra and between the prostatic vesicle and the neck of the bladder.

Structure.—The prostate gland is invested by a fibrous capsule continuous with the pubo-prostatic ligaments. Beneath the capsule is the prostatic venous plexus, which receives the dorsal vein of the penis, and joins the vesical venous plexus. The substance of the organ is composed partly of muscular and partly of glandular tissue. The

muscular tissue is both non-striped and striped. The non-striped muscle forms a portion of the anterior part of the gland in front of the urethra, as well as a considerable proportion of the base of the organ, where it is continuous with the sphincter vesicæ muscle. It forms a ring-like sphincter arrangement around the commencement of the urethra, by the division of which, in the lateral operation of lithotomy, the urethra and prostate can be dilated so as more readily to admit the forceps into the bladder.

The striped muscle of the prostate has been especially described by Kohlrausch and Henle. It is best seen at the apex of the prostate, where it is directly continuous with the striped fibres of the constrictor urethræ muscle which surround the membranous part of the urethra. It surrounds the urethra at the apex of the prostate, and doubtless acts as a sphincter muscle for it, so that Kohlrausch has named it *sphincter urethræ prostaticus*. Fasciculi continuous with this muscle also pass backwards as far as the sides of the neck of the bladder.

The glandular substance of the prostate consists of short branching acinous glands, which unite into a number of excretory ducts, that for the most part open on the floor of the urethra on each side of the colliculus seminalis. Both the ducts and the acini are lined by a columnar epithelium. Concretions are apt to form in old men in the ducts of these glands.

The prostate is penetrated by the urethra, the common ejaculatory ducts, and the prostatic vesicle.

The prostatic part of the urethra is the dilated commencement of that tube. It is about $1\frac{1}{4}$ inch long, is continuous behind with the bladder, and in front with

the membranous part of the urethra. It is nearly half an inch wide about the middle of the prostate, somewhat less where it opens into the bladder, and about a quarter of an inch in width at the apex of the gland, but it is capable of being more widely distended under pressure. It lies in front of the middle lobe of the prostate, and nearer its anterior than posterior surface. It is lined by a mucous membrane, which forms at the opening into the bladder a transverse fold, the *uvula vesicæ*. In front of the uvula a longitudinal fold about $\frac{3}{4}$ inch long, and $\frac{1}{8}$ th of an inch in its greatest height, extends forwards along the floor of the prostatic part of the urethra; it is called *colliculus seminalis*, or *verumontanum*, or *crest of the urethra*. On each side of this crest is a longitudinal depression, the prostatic sinus, into which many of the ducts of the glands of the prostate open. At the summit of the crest are three minute orifices, a mesial and two lateral: the mesial is the mouth of the prostatic vesicle, the lateral are the openings of the common ejaculatory ducts. The free surface of the colliculus is formed by the mucous lining of the urethra, beneath which, as Henle has shown, is a network of elastic fibres with interspersed non-striped muscle; cavernous tissue, capable of erection, occupies the spaces of this network.

The *vesicula prostatica*, or *utricle*, or *uterus masculinus*, is a pouch from $\frac{1}{4}$ to $\frac{1}{2}$ inch long, which opens by a narrow slit on the middle of the summit of the colliculus seminalis. It inclines backwards and upwards, between the lateral lobes, and below the middle lobe of the prostate, and though dilating somewhat in its course terminates in a cul-de-sac at its posterior free end. It is lined by a mucous membrane, covered by a stratified pavement epithelium, and its wall

contains fibro-muscular tissue, and some small tubular glands, which open on the free surface of its mucous lining. The ejaculatory duct is placed, for the terminal part of its course, in the wall of the prostatic vesicle. The vesicula prostatica is of great anatomical interest as representing in the male the uterus and vagina. In some mammals it possesses considerable size; in the horse and ass it is several inches long, and in the goat it divides into two horns posteriorly.

COWPER'S GLANDS.

Cowper's Glands are a pair of yellowish bodies, about the size of small peas, situated in the perineum, behind the anterior layer of the triangular ligament, and below the membranous part of the urethra. From each gland a duct proceeds, which runs forwards for about an inch, and opens into the bulbous dilatation of the urethra. The glands are composed of lobules, and have the compound racemose type of structure. Each gland is supplied with blood from a branch of the artery to the bulb.

THE URETHRA.

The Male Urethra is the excretory duct for the urine and seminal fluid. It extends from the neck of the bladder to the opening at the end of the glans penis. Its average length is from 8 to 9 inches, and it varies in length with the size and condition of the penis. In the erect state of the penis it forms a continuous curve, with the concavity directed towards the pubic arch. In the flaccid penis it makes, at first, a curve with the concavity directed towards the pubic arch; but when it reaches the penis it changes its direction, and forms a second curve, with the concavity directed downwards. It is lined by a mucous membrane continuous at one end with that of the bladder, and at the other with the tegumentary covering of the glans. The epithelial covering of the prostatic part of the mucous membrane is, near the bladder, laminated and with an arrangement of cells similar to the epithelium of the bladder, but in the rest of the urethra, as far forwards as the fossa navicularis in the glans penis, the epithelium is columnar. At the external orifice again it is stratified and squamous. Beneath the mucous membrane is the sub-mucous coat, in which, in addition to the fibres of connective tissue, there are non-striped muscular fibres arranged both longitudinally and circularly. Ellis has shown that the longitudinal fibres are continuous with the internal longitudinal muscular fibres of the bladder.

As the external relations of the urethra vary in different parts of its extent, it is divided into three parts, the prostatic, membranous, and spongy portions. The prostatic

part of the urethra has already been described ; the spongy part will be considered along with the penis; the membranous part will now be examined.

The *membranous part of the urethra* curves, with the concavity directed forwards, under the pubic arch, from the apex of the prostate gland to the bulbous portion of the spongy part of the urethra. It is the shortest part of the canal, measures about $\frac{3}{4}$ inch along its anterior wall, and about $\frac{1}{2}$ inch along its posterior wall. It is the narrowest part of the urethra, and in some cases apparently is not more than about $\frac{1}{2}$ inch in circumference, but it is capable of being more widely distended. It pierces the triangular ligament of the urethra before it joins the bulb, and diminishes somewhat in calibre as it passes through it; the fibrous membrane of this ligament supports and gives an investment to the membranous part of the urethra. It is also surrounded by the constrictor urethræ muscle. It is lined by mucous membrane, and its wall not only contains the nonstriped fibro-muscular elements met with generally throughout the urethra, but a vascular, cavernous venous plexus. A few racemose glands open on the free surface of its mucous lining.

The *Compressor* or *Constrictor Urethræ* is a striped muscle passing across the pubic arch, to the sides of which it is attached. In its course it completely surrounds the membranous part of the urethra, to which it acts as a sphincter muscle. It is quite distinct from the non-striped circular muscular fibres, in relation to the submucous coat of the urethra.

THE PENIS.

The Penis, or organ of copulation, is situated in the perineum in front of the triangular ligament and the pubic arch. It consists of a root, a body, and of the glans penis. By its root it is attached to the sides of the pubic arch : its body forms the bulk of the organ, whilst the glans is the terminal part in which is situated the orifice of the urethra. The base of the glans possesses a rounded border, or *corona*, behind which is a constricted *cervix*. The body of the penis possesses an upper flattened surface or *dorsum*, two lateral rounded surfaces, and an inferior rounded surface principally formed of the corpus spongiosum.

The penis is invested by thin, freely movable skin, destitute of fat and hairs. Anteriorly the skin forms a loose fold, the *prepuce* or *foreskin*, which may either cover the glans, or be "drawn backwards from it. The inner layer of the prepuce is reflected over the surface of the glans, and behind and below the urethral orifice forms a thin fold, the *frænum preputii*. The inner layer is smooth, thin, and moist, and has a muco-tegumentary character. Opening on its surface, more especially near the cervix, are the ducts of numerous sebaceous glands, the glands of Tyson, in which a peculiar odoriferous secretion is formed. The skin of the glans itself is covered with vascular and highly sensitive papillæ, and is firmly attached to the subjacent spongy tissue of the glans. At the root of the penis the integument is continuous with the hairy skin of the pubes and scrotum, and beneath the

skin is the *suspensory ligament*, which forms a triangular band passing from the symphysis pubis to the dorsum of the penis.

When the loose integument is removed from the penis, it is seen to consist of three longitudinal and parallel columns, the two corpora cavernosa, and the corpus spongiosum urethræ. The *corpora cavernosa* are the proper erectile parts of the penis, and form its dorsum, sides, and root. In the body of the penis they are closely united together, but at its root they diverge from each other and form the *crura penis*, which are attached to the sides of the pubic arch in front of the triangular ligament. Each crus is attenuated at its attached end, but in front of its place of attachment it dilates into the bulb of the corpus cavernosum. On the dorsum penis is a shallow groove, which marks the line of union of the corpora cavernosa on this aspect of the organ : on the under surface is a deep furrow, in which the corpus spongiosum is lodged. Each crus penis, and the part of the corpus cavernosum immediately continuous with it, is connected with the erector penis muscle. The *erector penis*, or *ischio-cavernosus* muscle, arises from the inner surface of the ischial tuberosity : it passes forwards in close contact with the under surface of the crus, and is inserted into the fibrous coat of the corpus cavernosum.

Structure.—The corpora cavernosa possess a dense white coat of fibro-elastic tissue, the *tunica albuginea*, which is not only prolonged from one cavernous body to the other, but forms a mesial septum between the two. This septum is perforated by numerous slits, which lie parallel to each other, so as to give it a comb-like appearance, hence the

name *septum pectiniforme* applied to it. From the inner surface of the external coat and from the septum numerous bands, or trabeculæ, arise, which intersect in various directions; they subdivide the space enclosed by the fibrous coat into numbers of small compartments, which are lined by an endothelium, continuous with that of the venous vascular system, and form a cavernous arrangement of veins. The trabeculæ are composed not only of fibro-elastic tissue, but of non-striped muscle, which is also prolonged over the inner surface of the tunica albuginea. The compartments between the trabeculæ freely communicate with each other in the same corpus cavernosum, and also through the slits in the septum with those in the opposite cavernous body.

The corpora cavernosa are supplied with blood by the cavernous branches of the two pubic arteries, which enter the crura penis, and by branches of the dorsal artery of the penis, which pierce the fibrous coat. They branch and run along the trabeculæ. They may terminate either in capillaries, or in the peculiar curling twigs described by J. Müller as the *helicine arteries*. The capillaries open directly into the venous intertrabecular spaces. The helicine arteries are chiefly found in the crura penis, and are apparently small convoluted arteries, which may end either in capillaries, or may form a blind termination. The veins of the corpora cavernosa arise from the cavernous venous spaces, by the distension of which with blood the erection of the penis is produced. The veins join to form not only the dorsal vein of the penis, but likewise the veins which accompany the cavernous arteries.

The *corpus spongiosum penis* is the part of the organ

which contains the urethra, and is situated on the inferior or perineal surface of the penis. It commences behind in the dilatation called the *bulb*, from which it passes forwards as a cylindriform body, and terminates in front in the expanded structure known as the *glans penis*. Its bulbous commencement is in contact with the perineal surface of the triangular ligament, and receives an investment from it. The bulb, and the part of the corpus spongiosum immediately continuous with it, are invested by the accelerator urinæ muscle.

The *accelerator urinæ* or *bulbo-cavernosus* muscle may either be regarded as a single muscle, the two lateral halves of which are united together by a mesial tendinous raphé, or as a pair of muscles. It arises from a point in the perineum, to which the levatores ani and transverse muscles of the perineum converge, also from the mesial tendinous raphé; the greater number of its fibres pass round the bulb and adjacent part of the corpus spongiosum to the perineal surface of the triangular ligament; but the most anterior fibres run outwards around the side of the corpus cavernosum, either to be inserted into the dorsum penis, or to end in a fibrous layer prolonged over the dorsum.

Structure.—The corpus spongiosum possesses a fibrous envelope, with trabeculæ and with intertrabecular venous compartments, but its coat is thinner, and the compartments are fewer and less distensible than those of the corpora cavernosa. The bulb receives a pair of special arteries, the arteries to the bulb, one from each internal pudic artery, which run forwards in the body of the corpus spongiosum; the dorsal arteries of the penis end in the glans

penis. These arteries branch, and the branches for the most part end in capillaries, which open into the intertrabecular venous compartments, but in the bulb helicine arteries are found. Veins arise in the corpus spongiosum, some of which join the dorsal vein, whilst others form veins corresponding to the arteries of the bulb.

The distinctive character of the corpus spongiosum is the presence of the urethra in it. The *spongy part of the urethra* is about six inches long. It is continuous behind with the membranous part, and when it enters the bulb presents a dilatation. In front of the bulb the urethra diminishes in calibre, and remains of uniform diameter until it enters the glans penis, when it again dilates into the *fossa navicularis*. The fossa terminates anteriorly at the constricted orifice at the end of the glans. The urethra, as seen in transverse section through the body of the corpus spongiosum, is widest transversely; in the fossa navicularis it is widest vertically, which is also its greatest diameter at the external orifice.

The mucous lining is covered, except near the orifice, by columnar epithelium, and opening on its surface are the ducts of numerous small racemose glands. Depressions or lacunæ also open on its surface, one situated in the roof of the fossa navicularis, and named the *lacuna magna*, being most conspicuous. External to the mucous membrane is a layer of non-striped muscle, together with a venous plexus.

The penis is well provided with lymphatics, which form networks in the glans, the prepuce, and around the mucous membrane of the urethra. They communicate with the inguinal glands in the groin. Nerves go to the skin of

the penis from the superficial perineal and long pudendal nerves, and to the substance of the organ from the cavernous and dorsal branches of the pudic nerve. The dorsal branch ends in the glans. Branches of the hypogastric plexus of the sympathetic accompany the arteries.

FEMALE ORGANS OF REPRODUCTION.

The essential organs of reproduction in the female are two genital glands, the Ovaries, in which are found the Ova, or Germ-cells. In close relation to the ovaries are the Fallopian tubes, the Uterus, and Vagina, along which the ova are conveyed. Should an ovum become impregnated, it remains lodged in the uterus until the development of the embryo is completed. When the child is ready for birth, it is expelled from the uterus along the vagina. The Fallopian tubes, uterus, and vagina constitute the genital tubes and passages. The Fallopian tubes are the excretory ducts of the ovaries, but are not anatomically continuous with them. Certain accessory organs, named the Par-ovaria, the Clitoris, the Nymphæ, the Vestibular Bulb, and the Mammæ, are also present.

THE OVARIES.

The Ovaries are two flattened oval bodies, in which the ova or eggs are found. They are situated in the pelvis, in connection with the posterior surface of the broad ligaments of the uterus (fig. 231). From their relation to that organ they necessarily change their position along with it, so that, when it enlarges during pregnancy, they rise with it into the abdomen proper. Each ovary is about $1\frac{1}{2}$ inch long, $\frac{3}{4}$ inch wide, and $\frac{1}{2}$ inch in thickness. It is attached to the broad ligament by its anterior border, which is sometimes called the *hilus*, for it transmits the vessels and nerves into and out of the organ. Its inner end is attenuated and attached to the upper lateral angle of the uterus, by the *ligament of the ovary*, into which the non-stripped muscular fibres of the wall of the uterus are prolonged. Its outer end, posterior border, and its two surfaces are free; but to its outer end one of the fimbriæ of the Fallopian tube is often attached.

Structure of the Ovary.

The surface of the ovary is partly smooth and partly marked with small cicatrices, which indicate the spots where the surface has given way to allow of the escape of the ova. The ovary is a solid gland, and consists of a surface epithelium, of a vascular stroma, of Graafian follicles, and of ova.

The *surface epithelium* forms a layer continuous with the endothelial cells covering the broad ligament of the

uterus, but is quite different in the shape of its cells. Instead of consisting of squamous cells, it is composed of short columnar cells, which have granular contents, so that the surface of the ovary has a duller appearance than that of the surrounding peritoneum. This columnar epithelium is the remains of the germ epithelium, covering the ovary in the embryo, from which the ova are derived. The line of demarcation between the columnar epithelial covering of the ovary, and the squamous endothelium of the peritoneum, is marked by a whitish, and often an elevated, line surrounding the attached border of the ovary.

The *stroma* of the ovary consists for the most part of connective tissue, in which numerous spindle-shaped connective tissue corpuscles are situated. Immediately beneath the surface epithelium the stroma forms the cortical layer, which at one time was described as a tunica albuginea, but is not now regarded as a separate coat. The stroma at and near the hilus has been named the medullary substance, and is very vascular; both the connective tissue and the vessels radiate from the hilus into the cortical layer. The medullary part of the stroma also contains bundles of non-striped muscle, which, as Waldeyer states, lie around the branches of the ovarian artery: they do not apparently enter the cortical layer.

The *Graafian follicles*, *ovi-sacs*, or *ovi-capsules*, are situated in the cortical layer of the ovary, and vary much in appearance with their stage of development. If a follicle in an advanced stage be examined, it will be seen to possess an external envelope of connective tissue, continuous with the stroma of the ovary, and containing a network of capillary blood-vessels. This forms the sac or wall of the

follicle, and the inner part of the wall is not so strongly fibrous as that which lies next the surrounding stroma. The inner surface of the wall of the sac is lined by some layers of cells which constitute the *membrana granulosa*, or so-called *epithelium* of the *Graafian follicle*. These



FIG. 227.—Section through the cortical part of the Ovary; *e*, surface epithelium; *s*, *s*, ovarian stroma; 1, 1, large-sized Graafian follicles; 2, 2, middle sized, and 3, 3, smaller sized Graafian follicles; *o*, ovum within Graafian follicle; *v*, *v*, blood-vessels in the stroma; *g*, cells of *membrana granulosa*.

cells are columnar, and possess elliptic nuclei: they have no cell wall, and are very delicate and soft in texture. At one spot they form a little mass called the *cumulus*, or *discus proligerus*, in which the ovum is imbedded. The Graafian follicle contains some liquid, secreted doubtless through the agency of these cells, and, as the secretion accumulates, the follicle approaches the

surface of the ovary by causing absorption of the surrounding stroma. The surface of the ovary then gives way, the wall of the follicle bursts, and the ovum and the liquid, with some of the cellular contents of the follicle, are discharged into the mouth of the Fallopian tube. The largest Graafian follicles can be readily seen with the naked eye, and measure from $\frac{1}{5}$ th to $\frac{1}{20}$ th inch in diameter. Graafian follicles of middle size have an average diameter of about $\frac{1}{50}$ th inch, and contain a much smaller amount of follicular fluid. The smallest Graafian follicles are arranged in large numbers in the cortex immediately subjacent to the surface epithelium. They are about $\frac{1}{100}$ th inch in diameter, contain no follicular fluid, and are lined by a single layer of the cells of the membrana granulosa, which are interposed between the ovum and the wall of the follicle. In rare cases two ova occur in a single follicle.

These modifications in the size of the Graafian follicles are especially seen during the sexually active period of life. In children they are almost uniformly of small size, and number, in all probability, between 30,000 and 40,000 in each ovary. After puberty, from twelve to twenty or thirty, may be seen at one time expanding into follicles of the largest size, a change in condition which indicates that in them the ova are becoming mature. After an ovum is discharged, through rupture of the wall of the follicle, the chink on the surface of the ovary heals, and forms a scar, and the Graafian follicle becomes occupied by a yellowish mass, called a *corpus luteum*.

The corpus luteum is a lobulated body closely invested by the wall of the follicle, which possesses about its centre an irregularly elongated greyish band, which is softer than

the surrounding lobules. The yellow mass is composed of cells, the protoplasm of which is finely granulated. Some of the cells are spherical in shape, but the greater number are elongated, and uni- or bi-caudate, in the latter case forming thick spindles; sometimes the caudate processes branch. The yellow mass is very vascular, its vessels being continuous with and derived from those in the wall of the follicle. The larger vessels lie between the lobules, and give rise to an abundant capillary network. The cells of the corpus luteum are derived from the cells of the membrana granulosa, which rapidly multiply and increase in size after the discharge of the ovum. In the course of time the corpus luteum shrivels up and disappears. Where an ovum has become impregnated, the corpus luteum remains for a much longer period than when impregnation has not taken place: the persistence being probably due to the greater flow of blood to the generative organs in the pregnant state, keeping up for a longer period the nutrition of the yellow body.

The *ovum* or *germ cell* is a globular body which attains a diameter of about $\frac{1}{120}$ th inch prior to being extruded from the Graafian follicle. The mature mammalian ovum is an example of a well-formed cell. It possesses a colourless envelope, the *zona pellucida* or *vitelline membrane*, which represents the cell wall: the zona usually seems to be perfectly pellucid; but a finely striated appearance has been described in it, which is believed to indicate the presence of minute pores. Within the zona is the *yolk protoplasm*, or cell contents, which contains numerous fatty granules. Imbedded in the yolk is the germinal vesicle or nucleus, about $\frac{1}{700}$ th inch in diameter, which

contains, not only a minutely granulated material, but a dark definite spot, the germinal spot or nucleolus, about $\frac{1}{3000}$ th inch in diameter. The zona pellucida is apparently formed by a differentiation of the peripheral part of the yolk protoplasm.

The ovary receives its supply of blood from the ovarian artery which enters it at the hilus. It divides into small branches in the fibrous medulla, which pass outwards to the cortex, and form capillary plexuses in the walls of the Graafian follicles. The veins which leave the ovaries form a well-marked plexus, called the pampiniform plexus, between the layers of the broad ligament. Lymphatics also pass out at the hilus: they form within the ovary a capillary plexus, and are continuous with lymph spaces situated around the Graafian follicles; according to His they pass into the substance of the corpora lutea. The nerves proceed from the sympathetic plexus which accompanies the ovarian artery, and have been traced towards the Graafian follicles, but their mode of termination is not known.



FIG. 228.—Ovum of a Sheep.
W, cell wall or zona pellucida; P, protoplasm or germ yolk; N, nucleus or germinal vesicle; NL, nucleolus or germinal spot.

Development of the Ovary and Ova.

From the observations of Waldeyer, it would seem that the ovary appears as a thickening, or small eminence, on the median aspect of the Wolffian body in the early embryo. It consists of two parts, a superficial epithelium, and a

subjacent tissue abounding in corpuscles, which projects from the interstitial tissue of the Wolffian body, and subsequently becomes the vascular stroma of the ovary. Both the epithelium and the vascular stroma of the ovary are differentiations of the cells of the mesoblast.

The superficial epithelium is named by Waldeyer the *germ epithelium*, for from its cells the ova are produced. It consists of columnar corpuscles, arranged side by side so as to cover the free surface of the ovary. Each germ epithelium corpuscle consists, as has been pointed out by J. Foulis, of an elongated, columnar-shaped nucleus, invested by so thin and delicate a layer of protoplasm, that the nucleus forms the most noticeable part of the corpuscle. The corpuscles are from $\frac{1}{2000}$ th to $\frac{1}{2500}$ th inch in their long, and about $\frac{1}{3500}$ th in their short diameter. Waldeyer showed that changes then took place in some of these germ epithelial corpuscles; the nucleus swelled out into a spherical body, the protoplasm around the nucleus increased considerably in quantity, a nucleolus appeared within the nucleus, and the corpuscles assumed a spherical form, and formed a primordial ovum. At the same time involutions of the columnar germ epithelium into the substance of the ovary are taking place on various parts of its surface, and some of the corpuscles of this involuted epithelium pass through modifications in form and structure similar to those seen in the epithelium on the free surface of the ovary, so that spherical corpuscles, or primordial ova, appear also in it. The sub-epithelial tissue, or ovarian stroma, now contains multitudes of fusiform connective tissue corpuscles, with some capillary blood-vessels. A coincident growth takes place in it, so that

it penetrates between and around the spherical corpuscles, and separates them from the columnar corpuscles on the outer surface and in the involuted germ epithelium. Collections of these spherical cells then become enclosed in the substance of the stroma of the ovary, and form the egg-chains and egg-clusters described by Pflüger and Waldeyer. As the examination of the developing ovary is made by means of vertical sections into its substance, the egg-chains appear as if enclosed in tubes, and have led to



FIG. 229.—Vertical section through the Ovary of the Human fœtus. *g, g*, germ epithelium, with *o, o*, developing ova in it; *s, s*, ovarian stroma, containing *c, c, c*, fusiform connective tissue corpuscles; *v, v*, capillary blood-vessels. In the centre of the figure an involution of the germ epithelium is shown; and at the left lower side a primordial ovum, with the connective tissue corpuscles ranging themselves round it.—After Foulis.

the impression that the ovary was a tubular gland. But, from Foulis's observations, it would appear that these so-called tubes are produced by sections through furrows and depressions between irregular prominences on the surface of the ovary, which prominences are owing to the expansion of egg-clusters situated under the germ epithe-

lium. Waldeyer believed that of the cells in the imbedded egg-clusters, some developed into ova, whilst others greatly multiplied in numbers and formed the cells of the membrana granulosa, whilst the surrounding vascular stroma formed the wall of the Graafian follicle. Hence he regarded both the ova and the follicular epithelium as derived from the germ epithelium. The researches of J. Foulis have led to a modification of this opinion. The primordial ova undoubtedly arise from imbedded spherical cells of the germ epithelium. But Foulis has traced delicate processes of the connective tissue stroma, with its characteristic fusiform corpuscles, penetrating between the individual cells of the egg-clusters, so as to separate these cells from each other, and to give to each cell a special envelope of stroma tissue. The connective tissue corpuscles of the stroma are closely applied to the peripheral part of the yolk protoplasm of the primordial ovum, so as to dimple its surface. The vascular stroma surrounding each primordial ovum then forms the wall of the Graafian follicle, whilst the fusiform connective tissue corpuscles rapidly proliferate into the cells of the membrana granulosa, which originally form only a single layer. According to this view, therefore, whilst the ova are specially modified germ epithelium cells, the cells lining the Graafian follicle are derived from the corpuscles of the connective tissue stroma. With the increase in the number of the cells of the membrana granulosa they become arranged in several layers, and the discus proligerus is produced; as the expansion of the follicle goes on, the liquor folliculi is secreted. The cells of the membrana granulosa have a diameter of about $\frac{1}{3000}$ th inch.

The primordial ovum is converted into the mature ovum, not only by growing larger, principally by an increased formation of the yelk protoplasm, but by the yelk becoming infiltrated with fatty granules. An investing envelope or zona pellucida is also produced. Reichert and many other observers supposed that the zona was formed from the cells of the membrana granulosa immediately surrounding the ovum, but it is more probably produced by a special differentiation of the peripheral layer of the yelk protoplasm. The germinal vesicle is the modified nucleus of a germ-epithelial corpuscle, and as this nucleus, not only in the unmodified germ epithelium cell, but in the early stage of growth of the primordial ovum, greatly preponderates in size over its investing protoplasm, it seems at first to be the most important constituent of the cell. About the time of the maturation of an ovum the germinal vesicle has apparently completed its function, for when the Graafian follicle has burst, and the ovum has escaped into the Fallopian tube, the vesicle can no longer be distinguished. The formation of primordial ova from the germ epithelium corpuscles comes to an end before the third year of extra-uterine life. Of the many thousands of primordial ova in each ovary, only a comparatively small number come to maturity, and the maturation of the ova ceases when the function of menstruation terminates.

PAR-OVARIUM.

The Par-ovarium, or Organ of Rosenmüller, is a small body situated between the two layers of the broad ligament in the interval between the ovary and the Fallopian tube. It consists of a group of short convoluted tubules, from twelve to twenty in number, arranged in a radiated manner, with the base towards the Fallopian tube, and with the apex towards the ovary, but having no connection with either structure (fig. 231). At the base a longitudinal tube often unites the convoluted tubes together. This longitudinal tube is developed in the sheep, cow, and pig into a canal, which extends along the side wall of the uterus and vagina to open near the orifice of the urethra, where it is named the canal or duct of Gaertner. The tubes of the par-ovarium are lined by epithelium.

FALLOPIAN TUBES.

The Fallopian tubes, or Oviducts, are not anatomically continuous with the ovaries, but are intimately connected with the supero-lateral angles of the uterus. They are two in number, and are placed one along the upper free border of each broad ligament. Each oviduct is from 3 to 4 inches long; at its uterine or attached end it is slender and cord-like, but it expands towards its outer or free end, and terminates in a number of delicate processes or *fimbriæ*, one of which is often attached to the surface of the ovary. These fimbriæ surround the mouth of the oviduct, which, though constricted at the orifice, opens into the wide, trumpet-shaped outer end of the tube.

The oviduct possesses four coats. The external or *serous coat* is continuous with the peritoneum forming the broad ligament. The *muscular coat* consists of an external longitudinal, and an internal circular layer of non-stripped fibres, continuous with the muscular wall of the uterus. Beneath the muscular coat is the *submucous coat*, formed of vascular connective tissue. The internal or *mucous coat* lines the Fallopian tube, and is continuous with the mucous lining of the uterus. It is elevated into longitudinal folds, and is covered on its free surface with a ciliated columnar epithelium; glands do not exist in the mucous membrane. At the external orifice the ciliated columnar epithelium is prolonged upon the inner surface of the fimbriæ, and on these processes it passes into the squamous endothelium of the peritoneum.

Though the oviduct is not directly continuous with the substance of the ovary, yet when ova are being shed, through rupture of the wall of the Graafian follicles, the fimbriated end of the Fallopian tube embraces the surface of the ovary, so that the ova can enter its mouth. The ovary therefore differs from glands generally in not having its excretory duct directly continuous with its secreting structure. The ovum is propelled along the duct, partly by the movements of the cilia, and partly doubtless by a peristaltic contraction of the muscular coat.

THE UTERUS.

The Uterus is the important organ which receives the ovum, and after impregnation retains it during embryonic life, until its development being sufficiently advanced, the period of parturition arrives, when the foetus is expelled from the uterus. In the non-impregnated state the uterus lies in the cavity of the pelvis, between the rectum and the bladder, and is about 3 inches long, 2 inches broad at the widest part, and not quite 1 inch thick. When the ovum is impregnated, the uterus increases greatly in size, rises into, and occupies a considerable part of, the cavity of the abdomen proper.

The uterus is compared in shape to a pear, and possesses a fundus, a body, and a neck. The *fundus* is the



FIG. 230.—The anterior surface of the Uterus and broad ligaments. *f*, fundus; *b*, the body, and *c*, cervix uteri; *bl*, broad ligament; *r*, round ligament; *t*, Fallopian tube; *p*, par-ovarium; *o*, ovary shown through the broad ligament.

broad, free, convex upper end, and projects slightly beyond the place of attachment of the two Fallopian tubes. The *body* is elongated, with its anterior and posterior surfaces

slightly convex, and with its side nearly straight. The *neck* or *cervix uteri* is the lower, somewhat constricted end, about one inch in length, the wall of which is continuous with that of the vagina.

The non-gravid uterus lies obliquely in the cavity of the pelvis, the fundus is directed upwards and forwards, the cervix and os downwards and backwards. The body is not quite straight, but is slightly curved, with the concavity towards the bladder, the convexity towards the rectum. The vagina forms an angle with the uterus at their place of junction, so that, whilst the axis of the uterus is in that of the pelvic inlet, the axis of the vagina lies almost in that of the pelvic outlet.

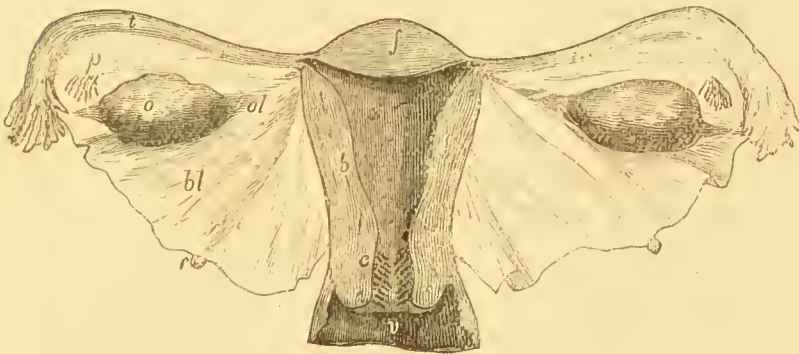


FIG. 231.—The posterior surface of the broad ligaments and the cavity of the Uterus. *f*, fundus; *b*, body, and *c*, cervix uteri; *v*, vagina; *bl*, broad ligament; *t*, Fallopian tube; *o*, ovary; *ol*, ovarian ligament; *p*, par-ovarium; *r*, round ligament.

The uterus possesses a wall of considerable, but not of uniform, thickness: for the posterior wall both of the body and cervix is somewhat thicker than their anterior wall, whilst the sides of the uterus, at the junction with the

Fallopian tubes, are generally thinner. The body of the uterus is hollowed out into a triangular cavity, which communicates at its base with the Fallopian tubes. The base of the triangular cavity is at the uterine fundus, the opposite end is at the cervix, where it communicates with the canal in the cervix by a circular constricted opening, named the *os uteri internum*. The cavity of the cervix is elongated and somewhat fusiform. The aperture of communication between the cervix and the vagina is transversely elongated, and named the *os uteri externum*. The os externum is bounded by two thick lips, the posterior of which is longer than the anterior, because the posterior wall of the vagina is prolonged higher on the uterus than is the anterior wall. From the oblique direction of the uterus, the anterior lip reaches lower down in the vagina than the posterior lip.

Structure of the Uterus.

The uterus possesses three coats, a serous, a muscular, and a mucous.

The *serous*, or external coat, covers the posterior surface of the neck and body, the fundus, the anterior surface of the body, but not the anterior surface of the neck of the uterus : it is also prolonged from the back of the cervix uteri on that part of the posterior wall of the vagina, which lies behind the posterior lip of the os uteri. It is reflected from the sides of the uterus, as the *broad ligaments*, which are prolonged to the sides of the pelvis : in front it is reflected to the bladder as the two *utero-vesical folds*, whilst behind it is reflected to the rectum as the two *utero-rectal folds* of

peritoneum. The interval between the uterus and the bladder, bounded laterally by the utero-vesical folds is the *utero-vesical pouch* of the peritoneum, whilst the interval between the uterus and rectum, bounded laterally by the utero-rectal folds, is the *utero-rectal pouch*, or pouch of Douglas. Both the utero-vesical and utero-rectal folds of peritoneum contain fasciculi of non-striped muscle, continuous with the muscular coat of the uterus. Those in the utero-rectal folds are most distinct, and extend backwards to the rectum in the region of the second sacral vertebra. Luschka conceives that they can draw the uterus backwards, and has named the arrangement the *musculus retractor uteri*.

The broad ligaments of the uterus are expanded folds of the peritoneum, which not only serve as lateral ligaments for the organ, but enclose the Fallopian tubes, the ovarian, and round ligaments, the par-ovarium and the vessels and nerves of the uterus and ovaries. The ovaries also are attached by their anterior borders to the posterior surface of the broad ligaments.

The *round ligament*, or *ligamentum teres*, is a round cord about five inches long, attached to the upper angle of the uterus, below and in front of the Fallopian tube. It passes forwards and outwards to reach the internal or deep abdominal ring; it then enters the inguinal canal, along which it passes, and leaves it at the external or superficial abdominal ring to end by becoming continuous with the subcutaneous tissue of the pubic region. The round ligament is chiefly composed of non-striped muscular fibres continuous with the muscular wall of the uterus, and some of these fibres spread out between the layers of the

broad ligament. Sometimes a prolongation of the peritoneum, named the *canal of Nuck*, accompanies the round ligament into the inguinal canal.

The *muscular coat* consists of non-striped muscle intermingled with areolar tissue, arranged so compactly as to form the thick, dense wall of the unimpregnated uterus. In the impregnated uterus the muscular wall expands and becomes less compact, during the growth of the organ, and the muscular coat is then seen to be arranged in three sets of fibres. The external set forms a thin layer immediately beneath the peritoneum, the fibres of which extend from the cervix over the body and fundus, and are prolonged into the round ligament, the ovarian ligaments, the wall of the Fallopian tubes, between the layers of the broad ligaments, the utero-rectal and utero-vesical folds. The middle set of fibres consists of longitudinal and transverse fasciculi, which intersect in various directions, especially at the sides of the uterus, where they surround the arteries and veins of the organ. The inner set of fibres forms the thickest part of the muscular coat. They are arranged in concentric rings around the sides of the fundus, from the place of junction of the Fallopian tubes to the middle of the body. In the cervix and around the external and internal os, they are arranged circularly, and form the sphincter muscles of those regions. The increase in size of the muscular coat during pregnancy is due to the formation of additional fasciculi, and to a considerable increase in size of the muscular fibre-cells.

The *mucous membrane* lining the uterus presents different appearances in the cervix and in the body of the organ. In the cervix it is elevated into two longitudinal

ridges, one on the anterior and the other on the posterior wall, to which a number of shorter ridges, directed obliquely downwards, converge, the whole forming an appearance known as the *plicæ palmatæ* or *arbor vitæ*. The epithelial covering of the mucous lining of the cervix is not at all times the same. In the virgin it consists of ciliated columnar cells, which extend as far as the *os externum*, where a squamous and stratified epithelium, like that of the vagina occurs. After the first pregnancy the ciliated epithelium is confined to the upper half or two-thirds of the cervical canal, whilst the lower part is lined with stratified squamous cells. In the lower part of the cervix vascular papillæ project into the epithelium. Simple and branched mucous follicles, lined by a ciliated columnar epithelium, open into the cervix, and in addition clear vesicles, filled with a yellowish fluid, and named the *ovula Nabothi*, are also found. In the pregnant uterus the glands of the cervix secrete a tenacious mucous, which plugs up the *os* and cervix.

The mucous lining of the body of the uterus is smooth and thin, and so closely set on the muscular coat that a definite submucous coat can scarcely be said to exist. It is covered by a ciliated columnar epithelium, the cells of which are not very elongated. Numerous small openings exist on the free surface of the mucosa, which are the mouths of the utricular glands. When vertical sections are made through the uterine wall, the utricular glands are seen to be elongated tubes, which branch once or twice in the course of their extent. It is not unusual to see two neighbouring glands join close to the free surface of the mucosa, and open by a common aperture. The glands do

not lie vertically to the free surface, as is represented in the well-known diagram by E. H. Weber, but run obliquely, or even in a slightly convoluted manner, so that in vertical sections they are often cut across, and only portions of the length of any single gland can usually

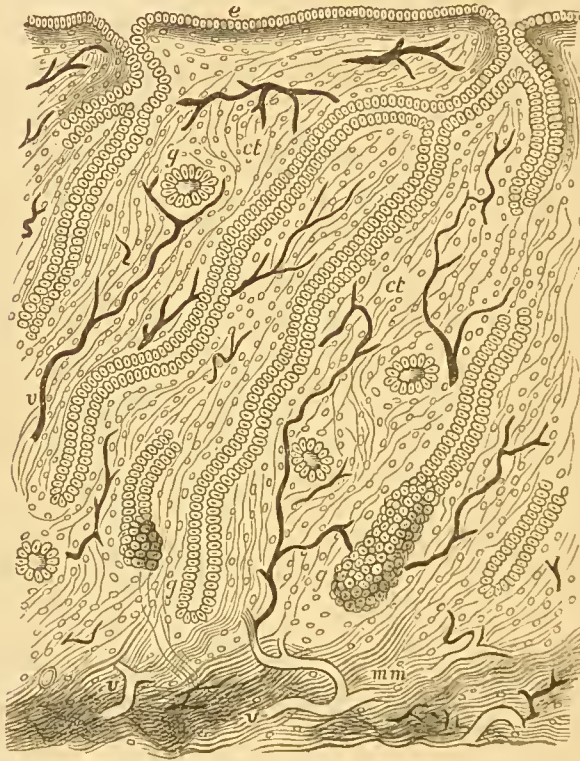


FIG. 232.—Vertical section through the mucous membrane of the Human Uterus. *e*, columnar epithelium—the cilia are not represented; *g*, *g*, utricular glands; *ct*, *ct*, interglandular connective tissue; *v*, *v*, blood-vessels; *m*, *m*, muscularis mucosæ. $\times 450$.

be seen. The closed ends of the glands reach as far as the innermost layer of the muscular coat, which sends prolongations around the deep end of the gland, and repre-

sents therefore, as J. Williams has stated, the muscularis mucosæ of the alimentary mucous membrane. The glands are lined by a columnar epithelium. In 1846 Allen Thomson observed, though he did not record the fact, that the epithelial lining of the uterine glands in the sow was ciliated. In 1852 Leydig published an account of the ciliated epithelium of the glands in this animal. Since that time Lott has recognised it in the cow, sheep, rabbit, mouse, and bat, and more recently Friedländer and J. Williams have observed it in the human female. The interglandular connective tissue contains multitudes of oval and elliptical corpuscles, which from their number give a marked character to the structure. In this tissue are distributed small arteries and veins, united together by a capillary plexus, which is distributed around the tubular glands.

The uterus receives its supply of blood from the two ovarian branches of the aorta and the two uterine branches of the internal iliac arteries. The uterine arteries reach the uterus at the sides of the cervix, and ascend in relation to the borders of attachment of the broad ligament, giving off numerous branches into the muscular wall. The ovarian arteries enter the folds of the broad ligaments, and not only give branches to the ovaries and Fallopian tubes, but send each a large branch to the side of the uterus, which supplies its wall in the region of the fundus, and freely inosculates with the uterine artery. The branches of the arteries in the muscular wall are tortuous, and the number and tortuosity of the branches increase greatly during pregnancy. The uterus is provided with numerous veins, which are thin walled, without valves,

and lie in close relation to the muscular fasciculi. They freely communicate with each other and give rise to the uterine and ovarian plexuses of veins. During pregnancy the veins within the muscular coat increase greatly in size, and form a cavernous-looking arrangement in the muscular wall. Lymphatic vessels form a network in the muscular wall, from which larger lymphatics proceed, that pass between the layers of the broad ligaments. From the observations of Leopold, it would appear that lymph spaces exist between the bundles of connective tissue of the mucosa, the walls of which spaces are formed of the flattened endothelial cells investing those bundles, and that similar endothelial sheaths invest the glands and blood-vessels. The nerves of the uterus arise from the hypogastric and spermatic plexuses of the sympathetic, and from the 3rd and 4th sacral nerves. Their arrangement and distribution have been investigated by Tiedemann, Robert Lee, Snow Beck, and Frankenhäuser. They form numerous plexuses, in which both medullated and non-medullated nerve fibres and nerve cells are found. They are distributed in the muscular wall, and Frankenhäuser states that the fibres can be traced into the nuclei of the contractile muscular fibre-cells. By some authors the nerves are said to increase in size during pregnancy.

THE VAGINA.

The vagina is the tube which extends from the uterus to the vulva. It is about 5 inches long, and curves from above downwards and forwards. Posteriorly it is related to the rectum, from which it is separated, in the greater part of its extent, by the thin recto-vaginal layer of the pelvic fascia, whilst between its upper end and the rectum is the bottom of the pouch of Douglas, lined by the peritoneum. Anteriorly it is related to the bladder and urethra, the latter of which is imbedded in the anterior wall of the vagina. Laterally, the levatores ani muscles and the visceral layer of the pelvic fascia are attached to it. This fascia gives a thin prolongation in front of the vagina, which at the same time encloses the urethra. The upper end of the vagina embraces the cervix uteri, and extends in a marked degree higher up behind than in front, so that the protrusion of the posterior lip of the os uteri into the vagina is much greater than that of the anterior lip. The lower end of the vagina opens in the vulva, at the bottom of the vestibule between the two nymphæ, and behind the orifice of the urethra; the diameter of this opening is somewhat less than that of the tube of the vagina.

Structure.—The vagina possesses an external coat of connective tissue derived from the pelvic fascia. Beneath this coat is the muscular coat, formed of fasciculi of non-striated muscle, arranged both longitudinally and circularly, which are continuous above with the muscular wall of the uterus. The inner coat is formed of the

mucous membrane which is elevated in the virgin into two longitudinal folds, one on the anterior, the other on the posterior wall, and into numerous transverse folds; these folds almost entirely disappear in women who have borne several children. The free surface of the mucosa is covered by a stratified squamous epithelium, into which numerous papillæ project. The ducts of numerous small mucous glands and follicles open into it; lymph corpuscles and lymph follicles are also scattered through it. It is supplied with blood by branches of the uterine, vesical, and vaginal arteries, derived from the internal iliac. The veins corresponding to these arteries form a vaginal plexus around it. Lymphatic vessels form plexuses in its wall. Its nerves, derived from the hypogastric plexus of the sympathetic, and from the 4th sacral and pudic nerves, also form plexuses in which are numerous microscopic ganglia.

The external orifice of the vagina is, in the virgin, to a large extent closed up by a fold of the mucous membrane, named the *Hymen*. This membrane does not form a complete partition, but is usually semilunar in shape, with the concave free border directed towards the pubes. At times the hymen passes completely round the orifice of the vagina, when it is pierced by a circular opening near the centre. In rare cases the hymen is imperforate. The hymen is ruptured in the act of copulation, and its remains form some papillary elevations around the orifice of the vagina called *carunculæ myrtiformes*.

The *Bulbo-cavernosus muscle*, or *compressor bulbi*, surrounds the orifice of the vagina and the wall of the vestibule. It is formed of striped muscle, which arises from

the central tendinous point of the perineum and from the perineal septum, to which are also attached the sphincter ani, transversi perinei, and levatores ani muscles. Its fasciculi run forwards and embrace the bulb of the vestibule, and are inserted into the crus clitoridis and into the upper part of the bulb. As its most anterior fibres are in relation to the urethra in the vaginal wall, Luschka regards it also as a sphincter of the urethra (fig. 233).

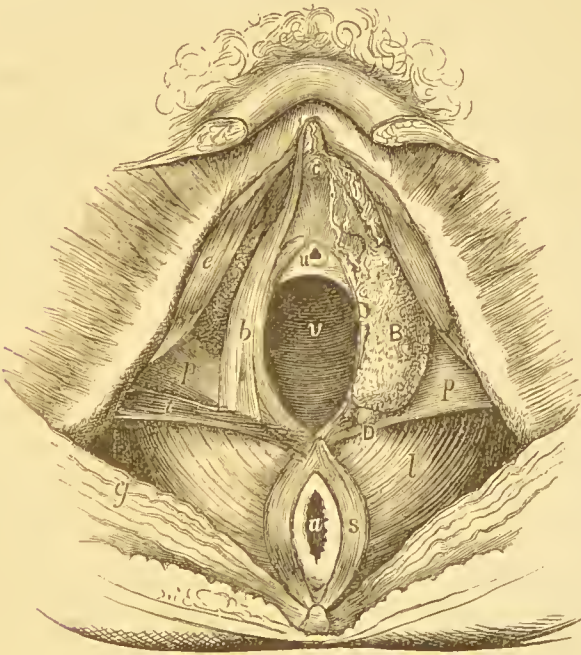


FIG. 233—Dissection of the female Perineum. *a*, anus; *v*, vagina; *u*, urethra; *s*, sphincter ani externus; *l*, levator ani; *g*, gluteus maximus; *p*, *p*, perineal septum; *t*, transversus perinei muscle; *b*, bulbo-cavernosus muscle; *B*, vestibular bulb; *D*, gland of Duverney; *c*, clitoris; *e*, erector clitoridis muscle. Modified from Savage.

The VESTIBULE is the interval between the nymphæ, in which the orifices of the urethra and vagina are situated.

At the orifice of the urethra are some slight folds of the mucous membrane. The *Nymphæ*, or labia minora, are two muco-tegumentary folds, which lie one on each side of the vaginal orifice, and form the lateral walls of the vestibule. When they are removed the bulbo-cavernosus muscle is exposed, and situated partially under cover of each half of this muscle is a highly vascular structure, the *Bulb* of the vestibule. The vestibular bulb is about one inch long, and consists of a complicated venous erectile network, the veins from which communicate with the vaginal plexus of veins and with the veins of the clitoris. A smaller venous plexus in front of the bulb has been named by Kobelt the *pars intermedia*. The two vestibular bulbs represent, in the female, the two halves of the erectile part of the bulb in the corpus spongiosum penis. The muco-tegumentary surface of the nymphæ is covered by a squamous and stratified epithelium, and opening on its surface are the ducts of numerous small mucous glands.

Two glands, named the *Glands of Bartholini*, or *Duverney*, or the *vulvo-vaginal* glands, open each by a long duct into the vestibule close to the orifice of the vagina. These glands vary in size from a pea to a small almond, and lie between the transversi perinei muscles and the posterior end of the bulbus vestibuli. They are homologous with Cowper's glands in the male, and like them possess the compound racemose type of structure.

At the anterior part of the vestibule is situated the *Clitoris*, a structure about $1\frac{1}{2}$ inch long, which represents in the female the penis of the male, but has no urethra enclosed in it. It is attached to the sides of the pubic arch by two crura, which become the corpora cavernosa

clitoridis and form the body of the clitoris. The anterior end of the clitoris forms a small and imperforate glans, which is invested on its superior surface by a preputial fold of the integument. The clitoris resembles in structure the penis. Each crus clitoridis is covered by an erector clitoridis muscle, that arises from the ischial tuber, and is inserted into the corpus cavernosum.

The clitoris, nymphæ, vestibule, and the orifices of the urethra and vagina are enclosed between two folds of the integument named *Labia majora*, or labia pudendi, which unite in front and behind at the anterior and posterior commissures. Immediately in front of the posterior commissure is a transverse muco-tegumentary fold named the *fourchette*. In front of the labia, the skin is elevated in front of the pubes into an eminence, the *mons Veneris*. The mons and the outer surface of the labia are covered with hairs.

THE MAMMARY GLANDS.

The Mammary Glands are accessory structures to the Reproductive system, and, at the termination of uterogestation, are engaged in the secretion of milk for the nutrition of the infant. They are two in number, and are situated one in each pectoral region. They form the rounded eminences named the breasts, and occupy in woman, when gravid or nursing, the region from the 3rd to the 6th ribs, and from the side of the sternum to the axilla. From about the centre of each breast the nipple projects, the base of which is surrounded by a pigment-stained ring or areola. The superficial surface of the gland

is in relation to the skin and subcutaneous fatty fascia; its deep surface rests on the aponeurosis covering the greater pectoral muscle.

The mammary gland is divided into primary lobes, separated from each other by lobules of fat. Each primary lobe is sub-divided into secondary lobes, and these again into lobules, whilst the lobules consist of rounded acini or gland vesicles. From these lobules slender branched ducts arise, and the ducts from adjacent lobules join together to form larger ducts, these again join to form still larger ducts, until at length from 15 to 20 large-sized milk ducts are formed, which converge to the nipple to open on its surface by as many orifices. Prior to entering the nipple the ducts dilate into sinuses, in which the milk collects during lactation.

The mamma is a compound racemose gland. The ducts are lined by an epithelium composed of short columnar cells. In the virgin the secreting cells within the acini are also columnar, but during lactation they swell out into polyhedral cells, and the gland vesicles at the same time become more dilated.

The gland is supplied with blood by the perforating branches of the internal mammary artery, the aortic intercostals, and the external mammary branch of the axillary artery, which end in capillary plexuses around the gland vesicles. Corresponding veins accompany these arteries. The anterior and lateral cutaneous nerves give branches to it.

In the male the gland is rudimentary, and the nipple, though small, is always present. Cases have been known in which the male mamma has developed so as to secrete

milk. Sometimes in young men at the time of puberty the mamma swells out a little and secretes a little thin fluid. Supernumerary mammæ in the human subject have been recorded by W. Gruber, P. D. Handyside, and other anatomists.

DEVELOPMENT OF THE URINARY AND REPRODUCTIVE SYSTEMS.

The Urinary and Reproductive Organs have close relations to each other, not only after their formation is completed, but in the region of their development.

In the early embryo the following structures are found in the abdominal region on each side of the mesial plane:—A Wolffian body; an excretory duct of the Wolffian body; a small body situated at the summit of the Wolffian body; a genital gland; a slender tube named the Müllerian duct lying on, but not communicating with, the Wolffian body.

The *Wolffian bodies* appear in the human embryo about the 3rd week as thickenings of the mesoblast lying in relation to the ventral surfaces of those protovertebræ, which correspond in position to the abdominal region. The mesoblast cells, out of which they proceed, lie between these protovertebræ and the line of division of the mesoblast into somato-pleure and splanchno-pleure, where they form a mass named the *intermediate cell-mass*. In the cell mass a tube or duct appears, from which diverticular offshoots arise, as a series of short convoluted tubes with vascular glomeruli, not unlike the structure of the kidney. From this resemblance in structure the Wolffian bodies are often called the *primordial kidneys*. The duct of each Wolffian body opens into the cloaca. After fulfilling until about the 6th or 7th week of embryonic life the office of kidneys, the Wolffian bodies atrophy, so that at the time of birth scarcely any trace remains. In the adult male the body known as the organ of Giralde's and the vas aberrans are the representatives of the Wolffian body; whilst in the adult female some fragments of tubes, called the graius of Folio, near the parovarium, are its persistent representatives.

The *permanent kidneys* arise from a mass of mesoblast cells situated in relation to the dorsal aspect of the Wolffian duct. As this mass increases in size it becomes hollowed out into minute tubes, the rudiments of the uriniferous tubes, which, as growth and development proceed, elongate and form the characteristic tubular structures of the kidney. These tubes then communicate with a tube, arising apparently in connection with the mesoblast, which becomes the ureter.

The *urinary bladder* is formed by a dilatation of that part of the allantois, which, by the development of the abdominal walls, be-

comes enclosed within the abdominal cavity. The allantois itself appears as a hollow bud-like diverticulum from the primitive hind gut, and grows not only into the pleuro-peritoneal cavity, but beyond the body cavity, so as to come into contact with the outer envelope of the ovum, and assist in the formation of the secondary or persistent chorion. The wall of the allantoic bud consists externally of cells derived from the mesoblast, which develop into a vascular connective tissue, and internally of cells derived from the hypoblast, which form the epithelial lining of the sac of the allantois, and are continuous with the hypoblast epithelial lining of the primitive hind gut. As the development of the walls of the abdomen advances, the part of the allantois connecting its extra-abdominal and intra-abdominal portions becomes attenuated into a slender peduncle, until finally, in the human subject, all communication between the two disappears. The intra-abdominal part of the sac becomes the urinary bladder, and the attenuated peduncle forms the urachus.

The *Genital Glands* in the two sexes arise in close relation to the Wolffian body from the same intermediate cell mass. The development of the *ovary* and *ova* has already been described (p. 832), and it has been shown that the ova arise by an involution and subsequent development of the germ-epithelium corpuscles covering the surface of the intermediate cell mass, in the seat of development of the ovary; whilst the vascular stroma of connective tissue, the walls of the Graafian follicles, and the cells of the membrana granulosa, proceed from the subjacent structures continuous with the interstitial tissue of the Wolffian body.

The *Testicle* is also produced in the same locality, but its tubular gland structure apparently proceeds from a differentiation of the cells of the subjacent interstitial tissue, and not from the superficial germ-epithelium, which loses its columnar form and probably becomes the squamous endothelium of the visceral layer of the tunica vaginalis testis. In the human embryo the sexual distinctness of the genital glands is said to be apparent about the 7th and 8th week, and, from Kölliker's observations, the tubes of the testicle can be recognised about the 10th week. Subsequently they grow longer, branch, assume their characteristic arrangement and structure, and form the tubuli seminiferi of the lobes of the testis, the vasa recta, and the rete testis. The more superficial parts of the interstitial tissue differentiate into the connective tissue of the tunica albuginea.

The small body situated at the summit of the Wolffian body

was first recognised as distinct from the Wolffian body by J. Cleland, and its structure has been investigated both by him and by W. M. Banks. It is formed of tubes, 12 to 18 in number, which run transversely from without inwards, and are slightly wavy in their course. Their outer ends are connected together by a common tube. This body does not contain glomeruli such as are formed in the Wolffian body. According to Banks, this body is converted in the male into the vasa efferentia, coni vasculosi, and globus major of the epididymis, and its tubes become continuous with those of the rete testis. In confirmation of this opinion of Banks's, I may refer to a congenital malformation that I described in 1865, in which the globus major was absent, and the testicle was not continuous with the body and globus minor of the epididymis. In this case the genital gland and the duct of the Wolffian body had been developed, but the small body at the summit of the Wolffian body had either not been developed, or had atrophied, so that the communication between the testicle and epididymis had not been established. In the female the small body becomes converted into the par-ovarium.

The *excretory duct of the Wolffian body* becomes dissociated from the proper tubes of that structure. In the male it is converted into the body and globus minor of the epididymis, the vas deferens, and the common ejaculatory duct, whilst the vesicula seminalis arises as a diverticular prolongation from it. The vas aberrans is probably a persistent portion of the tubular structure of the Wolffian body, which preserves its communication with the excretory duct, now converted into the tube of the epididymis. The tube of the body of the epididymis becomes continuous with that of the globus major. In the male, therefore, the excretory duct of the Wolffian body is converted into an important part of the genital apparatus. In the female, again, this duct almost entirely disappears, but it forms in certain animals the tubes called the *canals of Gaertner*.

The *Duct of Müller* is a slender tube, which is formed by an involution of the epithelium covering the intermediate cell mass, along a line immediately internal to the duct of the Wolffian body. The Müllerian duct opens at its anterior end into the peritoneal cavity, and as it passes backwards it lies in close relation to the Wolffian duct. The Müllerian and Wolffian ducts of the two sides become incorporated into a cord, named by Thiersch the *genital cord*, in which each tube is at first distinct. After a time the two Müllerian ducts become fused together posteriorly, and

form a common passage for a considerable distance ; but at their anterior ends they always remain distinct. The further development of the Müllerian ducts varies materially in the two sexes. In the male they almost entirely disappear, and are represented in the adult by the pedunculated hydatid of Morgagni, situated at the summit of the testicle, which is the persistent remains of the anterior end of the duct, and by the vesicula prostatica, which is the conjoined portion of the posterior ends of the two ducts that had coalesced in the genital cord. Banks is of opinion that the small cysts, sometimes situated alongside of the epididymis, may also be remains of the anterior part of the Müllerian duct.

In the female the ducts of Müller become greatly developed, and form the genital tubes and passages. The anterior end of each duct remains distinct, and becomes the Fallopian tube, whilst the posterior coalesced portions are converted into the uterus and vagina. The greater or less extent of this coalescence accounts for the production of the simple uterus, or the several varieties of double uteri that occur in different mammals, or that are found as variations in the human female. The tissue of the genital cord, which surrounds and connects together the Wolfian and Müllerian ducts, becomes converted in the male into the prostate gland, and in the female into the intermediate tissue between the urethra and vagina.

In both sexes the genital, urinary, and intestinal tubes open on the perineal surface of the embryo by a common outlet, or *cloaca*, up to the seventh or eighth week of embryo life. A partition then forms in this cloaca, which divides it into a posterior or anal part, and an anterior part, named the *uro-genital sinus*, which serves as a common space for the termination of the urinary Wolfian and Müllerian ducts. The female urethra and the prostatic part of the male urethra, situated above the vesicula prostatica and the orifices of the ejaculatory ducts, are formed from that part of the urogenital sinus which lies above the orifices of the Müllerian and Wolfian ducts ; whilst the lower part of this sinus ultimately forms the vestibule in the female, and the lower part of the prostatic and the membranous part of the urethra in the male.

A fold appears at the front of the uro-genital sinus, named the *genital eminence*, which differentiates into the penis or clitoris. In the male it is grooved on its under surface, and this uro-genital groove, by the development of a pair of folds, which grow together to meet below in the mesial line, subsequently closes in to form

the corpus spongiosum urethræ. In the female this closure does not occur, but the folds grow downwards and increase in size to form the nymphæ. The urethra has therefore no relation to the clitoris, but opens independently into the vestibule, or persistent lower part of the uro-genital sinus. The bulbs of the vestibule represent the bulbous part of the male corpus spongiosum, but from the absence of a corpus spongiosum urethræ in the female, they do not meet in the mesial line and remain as independent bilateral bodies.

At the sides also of the uro-genital sinus folds of integument arise. In the female they form the labia majora, and are separated from each other by the vertical fissure which communicates with the vestibule ; whilst in the male the two folds meet in the middle line of the perineum to form the scrotum, the line of union being permanently marked by the raised raphé of the scrotum.

In the development of the external organs of generation the female does not present so perfect a mesial union of the originally bilateral folds as takes place in the male, so that the female does not make so great an advance, but preserves certain arrangements which represent a transitional stage in the male development. The development of the internal organs in the two sexes shows much more important divergences. Thus in the formation of the male genital passages, whilst the Müllerian duct takes no part, the Wolffian duct is of primary importance. In the female, again, the genital passages are dilatations of the Müllerian ducts, and the Wolffian ducts do not contribute to their production. The genital glands, again, though arising in both sexes from the intermediate cell mass, yet owe their essential constituents to different portions of that mass of cells. For whilst the ova are special differentiations of the corpuscles of the germ epithelial layer on its surface, the seminal tubes, with their contents, are derived from the subjacent sub-epithelial tissue.

Owing to these differences in the development of the sexual apparatus in the male and female, the possibility arises of individuals being produced, possessing in a more or less strongly marked degree the characters of the two sexes. For example, the want of union of the two halves of the scrotum in the mesial line of the perineum would cause a mesial vertical cleft between the two lateral folds of integument ; if this were conjoined with the want of union of the two lateral halves of the uro-genital groove, the urethra would open, not at the end of the penis, but in the vertical mesial cleft. Externally, therefore, the individual might appear to have the

characters of a female, although the testicles might be present in the divided scrotum, and the ovaries and uterus be absent.

Again, in an individual otherwise possessing the characters of a male, if the Müllerian ducts were not to atrophy, but to undergo a certain commensurate enlargement, the prostatic vesicle would not appear as a rudimentary structure, but would exhibit, to a greater or less degree, the external characters of a vagina and uterus, situated between the rectum and the bladder.

The difference in the mode of development of the testicle and ovary also lends countenance to the possibility of both kinds of glands being produced in the same individual, a condition which has occasionally been seen in certain fish, as the codfish and herring, but examples of the occurrence of which have not been so definitely ascertained in the higher vertebrates.

It may, however, be stated that a structure sometimes found closely attached to the outer surface of the human testicle, and named by Luschka the non-pedunculated hydatid of Morgagni (to distinguish it from the pedunculated hydatid of Morgagni near the head of the epididymis), is, by the recent researches of Fleischl, in all probability the rudimentary *ovarium masculinum*. Its outer surface is covered by a cubical or short cylindrical epithelium, distinct from the squamous endothelium of the surrounding tunica vaginalis, which is involuted to some extent into its substance. Its proper substance consists of connective tissue, with convoluted canals, lined by a cubical or short cylindrical ciliated epithelium. Hence in the male a rudimentary representative of the ovary may be present, though functionally inactive.

The *Mammary glands* are developed in connection with the integument of the pectoral region. It has been customary to regard the epithelial lining of the ducts and gland vesicles as arising from an involution of the cells of the cuticular epiblast, whilst the ducts and the vascular connective tissue of the lobes proceed from the subjacent mesoblast. From the recent observations of C. Creighton, it would appear that the acini of the gland arise at many separate points quite independent of the ducts, and develop from the same kind of cells which give origin to the fatty tissue. The ducts themselves are formed by the aggregation of embryonic cells along certain lines, and are formed before the acini, with which they subsequently become continuous. Creighton's observations on the development of the mamma support Goodsir's view of gland development, according to which a gland is originally a mass of nucleated cells, the progeny of one or more parent cells;

whilst the membrane in connection with the embryo gland may, or may not, be prolonged in the form of a hollow cone into the mass; but, whether this happens or not, the extremities of the ducts are formed as closed vesicles, and then nucleated cells are formed within them, and are the parents of the epithelium cells of the perfect organ.

CHAPTER XIII.

THE PLACENTA.

THE impregnated ovum undergoes within the cavity of the uterus those structural changes which lead to the development of the embryo, and the formation of the placenta. The placenta is the organ that serves as the medium of connection, during intra-uterine life, between mother and foetus, and in which the physiological processes take place that are concerned in the nutrition of the foetus.

The placenta is a compound organ, and consists of two series of structures, the one belonging to the foetus, the Foetal Placenta; the other to the mother, the Maternal Placenta. In the diffused form of placenta occurring in the Pig, Mare, Zebra, Cetacea, Manis, Lemurs, and Camels, and in the Cotyledonary form of placenta of the typical Ruminants, the foetal and maternal parts of the placenta can be readily separated from each other. But in the zonary form of placenta occurring in the Carnivora, Hyrax, and the Elephant; in the dome-shaped placenta of the Sloths and in the discoid placenta of the Rodentia, Insectivora, Cheiroptera, Quadrumana, and the Human female, the foetal and maternal structures are much more intimately blended with each other.

THE FŒTAL PLACENTA is formed of certain membranes,

named chorion, amnion, allantois, and umbilical vesicle, the mode of formation of which will now be considered.

When the ovum becomes fertilised by the penetration of spermatozoa through the zona pellucida, developmental changes take place in it, which lead to the production not only of the embryo, but of the foetal membranes. The yolk undergoes cleavage, and becomes subdivided into multitudes of minute cells, each consisting of a nucleated clump of protoplasm. These cells form, immediately within the zona pellucida, a cellular membrane, the blastoderm, which surrounds the undifferentiated central part of the yolk, assumes a vesicular form, and is named the *blastodermic vesicle*. At one part of the blastoderm a roundish white spot then appears and forms the *area germinativa*, or area of formation of the future embryo. Commencing at the area germinativa the blastoderm splits into two layers, an outer, epiderm or epiblast, and an inner, hypoderm or hypoblast. Subsequently a third or intermediate layer is formed, the mesoderm or mesoblast.

Whilst these changes are taking place in the cells derived from the differentiation of the yolk, the zona pellucida, which was at first quite smooth, gives rise, at least in the dog and rabbit, to numerous short, simple villi, which form the villi of the *primitive chorion*. Whether or not similar villous outgrowths project from the zona pellucida of the human ovum has not yet been determined. These villi are, like the zona itself, perfectly structureless, and their apparent object is to attach the ovum in the early stage of gestation to the surface of the uterine mucous membrane. In a short time the primitive chorion disappears, and is replaced by the secondary or

permanent chorion, which forms the outer envelope of the embryo, and is the proper medium of attachment to the wall of the uterus.

The mode of origin of the *secondary* or *persistent chorion* has now to be considered.

From the margin of the area germinativa a delicate fold arises, which, by becoming more and more elevated, gradually extends itself above the back of the young embryo, until at last the folds from opposite sides meet in the middle line, become continuous with each other, and form the membrane of the *amnion*. Between the amnion and the back of the embryo is a space, the cavity of the amnion, which increases in size by the secretion of the liquor amnii into it. The amnion consists of two layers, an outer and an inner, and as it is derived from the area germinativa it is necessarily continuous with the blastoderm. The inner layer of the amnion, which lies next the amniotic cavity, consists of tessellated epithelial cells, is derived from the epiblast, and is continuous with the cuticular layer of the embryo. The outer layer of the amnion is a thin stratum, continuous with the somatopleure layer of the mesoblast, and formed of stellate and spindle-shaped cells, like the corpuscles of embryonic connective tissue. The amnion is the most internal of the foetal membranes, and forms an ovoid bag in which the foetus and liquor amnii are contained.

But before the amniotic folds meet to become continuous with each other, the free edge of each fold is bent outwards, and, by a continuous process of growth, gradually spreads around the ovum, immediately within the zona pellucida, so as to form a layer, which was named by Von

Baer the serous envelope of the ovum, but which may more appropriately, from its position within the zona, be named the *sub-zonal membrane*.. When the union of the amniotic folds has taken place, the sub-zonal membrane becomes completely severed from the proper amnion, and constitutes one of the layers of the secondary or persistent chorion. The sub-zonal membrane consists essentially of a layer of cells, which was originally continuous with the cellular layer lining the inner surface of the proper amnion, and through it with the epiblast cells forming the cuticular covering of the embryo. But it is not unlikely that, along with this cell-layer, a thin prolongation of the layer of stellate connective tissue corpuscles of the somatopleure layer of the mesoblast is present. Between the sub-zonal membrane and the proper amnion a space exists, continuous with the general pleuro-peritoneal cavity of the embryo, which is of interest, in connection with the formation of the permanent chorion, as the space into which the allantois grows and expands..

Whilst the changes in the epiblast and somatopleure, which lead to the formation of the amnion and sub-zonal outer layer of the persistent chorion, are taking place, the hypoblast and adjacent splanchnopleure gradually extend over the undifferentiated part of the yolk, which they enclose in a sac, the *yolk-sac*, or *umbilical vesicle*, and at the same time they form along the ventral surface of the embryo an elongated tube, the alimentary canal. This canal at first freely communicates with the yolk-sac, but as the walls of the alimentary canal thicken and become more closed in, the communication narrows, until at length the omphalo-mesenteric duct forms the only channel

of communication between the umbilical vesicle and the intestine. In the splanchnopleure forming the wall of the umbilical vesicle, and in the corresponding wall of the alimentary tube, blood-vessels are developed. As that pole of the umbilical vesicle, which lies opposite the omphalo-mesenteric duct reaches, and is, and at an early period of its development, in contact with a limited area of the sub-zonal membrane, the blood-vessels in the wall of the vesicle may be, and in some mammals are, conveyed by it up to the sub-zonal membrane.

In some mammals, as in the Pig, Mare, Cetacea, and Ruminantia, the umbilical vesicle disappears as development advances, so that no trace of it can be seen in the membranes of an advanced embryo. In others, as the Human subject, it persists, according to Schultze, even up to the end of intra-uterine life, as a minute vesicle at the placental end of the umbilical cord. In the Carnivora and Pinnipedia again it forms a well-defined sac, in relation to the abdominal aspect of the foetus, situated between the allantois and amnion, and prolonged laterally into two horns. In the Bitch I have seen its vessels persistent, and forming a well-defined plexus in its wall, though they did not reach the chorion. In the Rabbit, and probably also in other Rodentia, the umbilical vesicle reaches the chorion, and forms a large sac in contact with a considerable portion of that membrane, to which it conveys blood-vessels: but the discoid placenta of the rabbit apparently derives its foetal vessels only from that part of the chorion which receives its vascular supply from the allantois.

An important change also takes place at the pelvic end

of the alimentary tube. The small vesicular outgrowth, named the *allantois*, rapidly increases in size, grows into the space between the umbilical vesicle, amnion and sub-zonal membrane, and becomes more or less intimately united with these structures, but more especially with the sub-zonal membrane, and its extra-abdominal part forms a dilated bag, the sac of the allantois, which contains the allantoic fluid. This sac keeps up its continuity with the urinary bladder by a slender tubular stalk, the urachus, which passes through the abdominal wall at the umbilicus. The wall of the sac of the allantois, having reached the inner surface of the sub-zonal membrane, spreads itself over the whole, or a great part of that surface, and forms the inner layer of the permanent chorion. The allantois is lined by an epithelium continuous with the hypoblast epithelial lining of the intestine, whilst external to the epithelium is a layer of connective tissue, continuous with and derived from the splanchnopleuric layer of the mesoblast. In this connective-tissue layer blood-vessels are developed, which are continuous with the abdominal vessels of the embryo. When the sac of the allantois reaches the sub-zonal, or external, layer of the permanent chorion, the blood-vessels are necessarily brought there at the same time, and, as the allantois grows to form the inner layer of the chorion, its blood-vessels become the vessels of the permanent chorion, or the vessels of the fetal placenta. These vessels increase in size and numbers with the growth of the chorion, their trunks become the umbilical arteries and vein, they enter into the formation of the umbilical cord, and pass into the abdominal cavity, at the umbilicus, to join the aorta and inferior vena cava.

appears, either by becoming incorporated with the sub-zonal membrane, so as no longer to be recognised as an independent membrane, or by becoming absorbed. The sub-zonal membrane, or serous envelope of the ovum of Von Baer, originally continuous with the amniotic folds, and through them with the epiblast layer of the blastoderm, persists, and forms the epithelial, non-vascular epiblast layer of the persistent chorion, and of the villi which grow from it. The allantois forms the inner or vascular layer of the persistent chorion, and the vascular matrix of the villi; but in some of the Rodentia, the umbilical vesicle reaches and remains in contact with a limited portion of the sub-zonal membrane, to which it conveys connective tissue and blood-vessels. The persistent chorion, therefore, is a compound membrane, produced secondarily during the process of development by the union of the sub-zonal, epiblast membrane, from which its epithelial layer is derived, with the allantois, from which it derives its blood-vessels and connective tissue; and like the embryo itself it arises from the layers of the blastoderm.

The allantois undergoes considerable modifications in both size and general disposition in the different orders of mammals. In many mammals, as the Pachydermata, Ruminantia, Cetacea, Carnivora, Pinnipedia, the Lemurs, and the Scaly Anteaters (*Manis*), the sac of the allantois persists as a distinct chamber, and contains a considerable quantity of allantoic fluid. Of the opposite walls of the sac, the one lines, to a greater or less extent, the inner surface of the permanent chorion, which is coated therefore by the epithelial lining of the allantois; the other invests, to a greater or less extent, the outer surface of

the amnion, which is covered therefore, in whole or in part, by the wall of the sac of the allantois. As a consequence of this arrangement, the bag of the amnion in these mammals is altogether, or in great part, separated from the inner surface of the permanent chorion.

So large and persistent is the sac of the allantois in the ordinary Ruminantia, in the Camelidæ, Tragulidæ, Solipeda, and cloven-hoofed Pachydermata, that M. H. Milne-Edwards has grouped them together as *Megallantoids*; whilst he has placed the Carnivora and Pinnipedia, from the smaller size of the sac of the allantois, in a *Mesallantoid* legion of mammals. The Rodentia, Insectivora, Cheiroptera, Quadrumana, and Man are characterised by the small size of the sac of the allantois, or even by its complete disappearance as an independent chamber: hence Milne Edwards has grouped them together in a *Micrallantoid* legion. The disappearance of the allantois as a distinct sac is correlated with the great expansion of the amnion, and increase in the amount of amniotic fluid. As the bag of the amnion expands it grows outwards towards the chorion, and in the Sloths, the Apes, and the Human Female, reaches, and adheres, through the intermediation of a gelatinous connective tissue, to the inner surface of that membrane, so that when the chorion is cut through, the amnion is at once exposed.

The chorion is the most external of the foetal membranes. When first formed, it is globular or ovoid in shape. In uniparous mammals, as the Sloths, the Apes, and the Human Female, where the uterus is single, it preserves, with but little alteration, this form throughout intra-uterine life; but in most uniparous mammals, where the uterus

possesses two horns, the chorion becomes greatly elongated, and extends as far as the ends of both horns.

In the Human ovum all trace of the zona pellucida has disappeared before the 10th day, and the secondary chorion, as Reichert's observations show, is then an epitheliated membrane, with unbranched villi projecting from, but not completely covering, its outer surface. At the 2nd week the chorion is covered with villi, which at the 3rd week are branched, and about the 4th week have acquired blood-vessels, from the growth into them of the vessels of the allantois. About the 6th week some of the villi begin to atrophy, and at the end of the 2nd month, when the ovum has attained the size of a hen's egg, the villi have disappeared from one pole, and are arranged over a discoid surface, which represents the placental area throughout the remaining period of gestation. In the mature placenta the villi are very arborescent, and extend from the chorionic to the decidual surface; the terminal branches, which lie next the decidua, being attached to the placental surface of that membrane. The chorion and the basis substance of each villus are formed of a gelatinous connective tissue continuous with a similar tissue in the umbilical cord. In it the branches of the umbilical vessels ramify, and the capillaries form simple or sometimes double loops in the collateral terminal branches of the villi. Each villus is invested by a layer of cells, which have been recognised by anatomists since Dalrymple figured them upwards of thirty years ago, and to which Goodsir gave the name of the external cells of the villus. These cells are somewhat flattened, though not squamous, are rectangular in outline, and closely applied to each other

by their margins, so that they form a continuous layer. This layer of cells can be peeled off the villus, and belongs, as was stated by Goodsir, to the cellular structure of the decidua, which has become adherent to the villi in the course of the development of the placenta.

The MATERNAL PLACENTA is formed by a special modification of the uterine mucous membrane.

When the fertilised ovum is received into the cavity of the uterus the mucosa undergoes important changes. It swells up, becomes thicker, softer, and more vascular. Its epithelial covering loses its columnar form; its glands enlarge, and their orifices become more distinct; the interglandular tissue increases largely and rapidly in quantity, by a multiplication, not only of the cells of the surface-epithelium, but by a proliferation of the corpuscles of the sub-epithelial connective tissue, so that the glands are separated from each other by a much greater amount of interglandular tissue than in the non-gravid state; the blood-vessels not only increase in numbers but in size. At the same time the free surface of the modified mucosa becomes divided into a number of irregular areas by furrows, and on the free surface of these areas, more especially near the furrows, the mouths of the utricular glands may be seen to open in considerable numbers. The modified mucosa constitutes the *decidua vera* or *uterina*.

The fertilized ovum attaches itself to the surface of one of these areas; and the decidua, immediately surrounding the place of attachment, grows around the ovum so as to enclose it and to form the *decidua reflexa* or *decidua ovuli*; the place of junction of the decidua, growing up from opposite sides of the attached border of the ovum, being

marked by a pellucid spot named the umbilicus or scar. The ovum is thus enclosed in a distinct chamber, the *ovigerous* or *ovular chamber*, and the decidua reflexa shuts off the ovum from the general cavity of the uterus. The free surface of the decidua reflexa, except at and close to the scar, is perforated by the mouths of the enlarged utricular glands. Dilated veins continuous with those in the decidua uteri are prolonged into the decidua reflexa.

The portion of the decidua uterina, forming the surface of the area to which the ovum becomes attached, undergoes a great development, forms the maternal part of the placenta, and is named the *decidua placentalis* or the *decidua serotina*. In two specimens which I examined at about the 3rd or 4th week of utero-gestation, I found the surface of the decidua serotina next the ovular chamber to be subdivided into shallow irregular spaces, occupied by the villi of the chorion. The decidua was nearly $\frac{2}{10}$ ths inch in thickness, and had a loose spongy appearance. On making vertical sections it was seen to contain numerous cells, some of which were polygonal, others rounded, and of large size, and with large nuclei; others were caudate, and between the cells was a delicately fibrillated connective tissue. Amidst this cellulated tissue numerous dilated vessels were also seen in section, many of which were entirely, or to a large extent, filled with blood corpuscles. These dilated vessels were neither arteries nor veins, but dilated capillaries, for they possessed merely a simple cellular wall, fused with that of the tissue in which they were situated. At this early period of gestation, therefore, the capillaries of the uterine mucosa in the placental area exhibited a sinus-like dilatation. Here and there an utri-

cular gland might be seen either longitudinally or transversely divided, but the number of glands in a given area was much fewer than in the non-impregnated mucosa, so that the increase in area of the decidua was obviously due to a great increase in the amount of interglandular connective tissue.

The villi of the chorion were intimately adherent to both the surface of the decidua reflexa and the serotina forming the wall of the ovular chamber. This adhesion was due to an up-growth of the decidua between and surrounding the villi, so that the fixing and interlocking of the foetal and maternal structure seem to be due to a coincident growth both of villi and decidua, whereby the villi, even at this early stage of placental development, are ensheathed by the cell structures of the decidua.

It has been customary for anatomists to state that the attachment of the villi to the decidua, not only in the human placenta, but in placentæ generally, is due to the penetration of the villi into the tubes of the dilated utricular glands. The researches made by Ercolani and by myself, during the last few years, on the various forms of placenta in different groups of mammals, have however shown that the villi are not lodged in these glands, but are received in crypt-like depressions on the surface of the mucous membrane, formed during gestation by a hypertrophy and folding of the mucous surface. For not only are the glands much fewer in number than the villi and the crypts which contain the villi, but in many mammals, as the pig, the mare, the lemurs, and the true ruminants, the glands can be seen to open on the free surface of the uterine mucous membrane in areas quite distinct from the crypts.

This arrangement applies also to the human placenta; for the utricular glands, which open, on the free surface of the decidua serotina, into the ovular chamber, are much fewer than the villi of the chorion attached to that surface of the chamber; whilst the uterine glands in the decidua reflexa open on that surface of the decidua which is next the general cavity of the uterus. The up-growths of the decidua around the villi of the human chorion are comparable therefore with the foldings of the uterine mucosa, which in the cat, pig, cow, and other mammals constitute the walls of the crypts in which the villi are lodged.

But the interlocking of the foetal and maternal parts of the human placenta may be advantageously studied at a later stage of development. About the 5th month, when the decidua reflexa and the villi connected with the non-placental area of the chorion have atrophied, whilst the villi in the placental area have undergone a great increase, both in length and in the number of branches, the placenta has then assumed a definite discoid form. Well-marked bars or dissepiments of decidua serotina pass through the thickness of the placenta as far as the chorion, and divide it into lobes or cotyledons. Numbers of more slender decidual bands pass into the substance of each lobe, partly from the surfaces of the dissepiments, and partly from the general surface of the serotina between the dissepiments. These bands give rise to still more delicate offshoots, which form a microscopic intraplacental trabecular arrangement in the interspaces of which the villi are lodged. These intraplacental prolongations of the decidua are applied to the stems and branches of the chorionic villi, and the interspaces containing the villi are comparable to the cavities

of the crypts in the placenta of the pig, fox, bitch, sheep, and other mammals.

The bands of decidua principally consist of large, distinctly nucleated, rounded or polygonal cells, lying in a delicately fibrillated connective tissue. The more slender offshoots contain, at their origin, similar cells, but to a large extent are made up of delicate fibrillated connective tissue containing scattered corpuscles. Although this tissue is often in close apposition to the villi, it may be separated from it by appreciable intervals, and, from its extreme delicacy, has the appearance as if it were being so attenuated by the growth and expansion of the placenta, that it is undergoing atrophy. The maternal blood-vessels, the capillaries of which, as already stated, have dilated into sinuses, are also prolonged into the placenta, along with the cellular structures of the decidua serotina, so that the dilated vessels of the modified uterine mucous membrane are brought into relation with the vascular villi of the foetal chorion.

In the placenta, at and near the full time, the growth and expansion of the organ have made so great an advance, that the original relations of its foetal and maternal constituents have become greatly modified, so that some observers have questioned, though erroneously, if maternal structures enter at all into its internal construction.

The Mature Placenta presents the appearance of a disc-shaped spongy cake, from 7 to 9 inches in diameter, and about 1 inch thick about its centre, where the umbilical cord is continuous with its chorionic surface; towards its circumference it is always somewhat thinner. Its inner or chorionic surface shows the ramifications of the umbilical

vessels, and is closely covered on its foetal side by the amnion, whilst from its placental side multitudes of arborescent vascular villi arise. Some of these villi are comparatively short, but the greater number are so long that their terminal branches reach, and are often attached to, the placental surface of the decidua serotina.

The outer, attached or uterine surface of the placenta, is formed by the placental decidua, decidua serotina, or modified uterine mucosa of the placental area. The placental decidua is continuous at the margin of the placenta with the decidua vera, and it usually turns over the border of the placenta on its chorionic surface, and forms a more or less strongly marked band extending around its circumference. When separated from the uterus the outer surface is seen to be covered by a layer of the decidua serotina, which presents a flocculent appearance where it has been torn away from the uterine wall. It is marked by furrows, and bands of the decidua pass into the substance of the placenta at these furrows, and extend through its substance up to the chorion, so as to divide it into lobes or cotyledons. As these inter-lobular dissepiments are often imperfect, the lobes are not completely shut off from each other. Slender processes of the decidua serotina proceed both from the surface of the dissepiments, and from the placental surface of the serotina generally, into the interior of the lobes, but they can only be traced for a short distance, as they do not form a continuous framework of maternal tissue, such as exists in the placenta at the fifth month. Delicate threads of decidua may, however, occasionally be seen passing between the villi, and connecting them not only with each other, but with the decidual dis-

sepiments, or with the general surface of the serotina. These threads are without question the remains of that intra-placental arrangement of decidua, occurring so abundantly at the fifth month, but which has become attenuated and atrophied, in the fully formed placenta, in correlation with the great expansion of the intra-placental maternal sinus system.

A number of peculiarly tortuous arteries, continuous with the convoluted uterine arteries in the muscular wall, and named the *curling arteries* of the placenta, pierce the decidua serotina, and open on its placental surface by obliquely directed mouths situated between the terminal branches of the villi attached to the decidua serotina. The decidua serotina is also traversed by dilated *utero-placental veins*, which communicate with the venous sinuses in the muscular wall of the uterus. The utero-placental veins form in the decidua serotina a system of intercommunicating sinuses. Some of these veins are prolonged into the decidua dissepiments between the placental lobes; others lie in the thickened border of the decidua surrounding the circumference of the placenta, where they form the so-called circular sinus of the placenta. Not only the circumferential, but the other utero-placental veins freely communicate with the interior of the placenta, but their mode of opening into it is peculiar. Instead of possessing large patent mouths, the wall of the vein, where it lies in relation to the interior of the placenta, is perforated by one or more small apertures, so that it possesses a cribriform appearance; and not unfrequently a terminal offshoot of a placental villus may be seen to protrude through one of these small holes in the venous coat into the lumen of the vein.

It is clear, therefore, that the curling arteries and utero-placental veins open into the interior of the placenta, so that a stream of maternal blood flows through the placenta in its passage from the curling arteries to the utero-placental veins.

In a placenta still attached to the uterus, the spaces in its interior, through which the maternal blood circulates, may be injected either from the uterine arteries or veins; and in a separated placenta, if an injecting

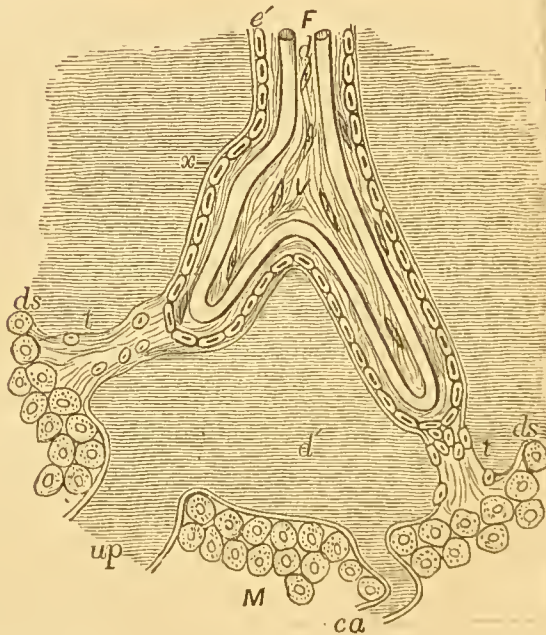


FIG. 235.—Diagram of the minute structure of the Human Placenta. F, the fetal placenta represented by V, a chorionic villus; *d*, the fetal capillaries within the villus; *e*, the cellular investment of the villus derived from the decidua serotina; M, the maternal placenta; *ds*, the cells of the decidua serotina; *t*, *t*, trabeculae or slender offshoots of the serotina passing to the fetal villus; *ca*, curling artery; *up*, utero-placental vein; *d'*, the shaded space to represent the intra-placental maternal sinus system; *x*, a thin layer superficial to the cellular investment of the villus to represent the wall of the maternal sinus vessel.

pipe be introduced into one of the lobes of the organ,

the utero-placental veins may be injected from it. The spaces in the interior of the placenta for the transmission of the maternal blood have been variously termed the cavernous spaces, the placental sinuses or lacunæ, the cells of the placenta, the intervillal spaces, and the placental bag or sac; they freely communicate with each other, not only in the same lobe, but in adjacent lobes, through imperfections in the interlobular dissepiments. These spaces belong to the maternal vascular system, and they are obviously an expansion of the dilated capillaries to be seen in the decidua serotina as early as the first month of gestation. Owing to the expansion of the intra-placental maternal capillaries into these irregular sinuses, a thinning and expansion of the vascular wall has at the same time taken place, so that it cannot, as a rule, be recognised as a distinct layer bounding the maternal sinus; but one may sometimes see a layer of great delicacy on the exterior of the villus, between its cellular covering, already described, and the maternal blood space, which from its position represents the wall of the intra-placental maternal vessels.

As to the cellular investment of the villus, at first sight it may appear to be only its proper epithelial covering derived from the outer epithelial layer of the chorion. But the cells are not squamous; they differ therefore from the epithelial covering of the chorion, and can readily be stripped off the villi. I am of opinion that they are derived from the intra-placental prolongations of the decidua. Through the expansion of the maternal sinuses, the cells of the decidua, situated superficially to the dilated capillaries, have been pressed so closely to the villi as to become incorporated with them, and apparently to form a part of their

texture. This opinion is based not only on the examination of the human placenta, but on the study of the comparative anatomy of the organ in a considerable number of mammals. For in every case a layer of maternal epithelium, derived from the uterine mucosa, was found interposed between the foetal vessels of the chorionic villi and the vessels of the maternal part of the placenta; whether the maternal vessels were simple capillaries, as in the diffused and cotyledonary forms of placenta, or dilated capillaries, as in the zonary placenta, the dome-shaped placenta of the sloth, or the discoid placenta of the ape and the human female.

As regards the function of this layer of epithelium throughout the placental series, I agree with Ercolani in regarding it as a secreting epithelium, which separates and prepares from the maternal blood a secretion, to be absorbed by the vessels of the chorionic villi, and applied to the nutrition of the foetus. The passage of material from the maternal to the foetal system of vessels is not a simple percolation or diffusion through their walls, but is occasioned by the action of cells. The placenta, both in its function and in the relative arrangement of its constituent textures, is therefore a specially modified secreting gland, the excretory apparatus of which is represented, not by a system of ducts, but by the blood-vessels of the foetal villi.

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